

SEEING STARS

The BBC Television Series

PATRICK MOORE

BBC tv



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cover photograph:
The Dumb-bell Nebula.

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British Broadcasting Corporation

1 Our Spaceship, the Earth

opposite page:
Photograph of the
Earth, taken from over
200,000 miles away.
Africa is clearly shown,
with the Red Sea and
the Mediterranean.

We live upon a whirling spaceship. It is a natural body, and it is more than four thousand million years old; but it is a spaceship none the less. We call it the Earth – our home.

Ancient peoples believed the Earth to be flat, and to be motionless. Nowadays we know better. The Earth has been found to be a globe almost 8000 miles in diameter, and it is not fixed in space; it is moving round the Sun, taking one year to make a full journey. It is also spinning round, carrying us all with it.

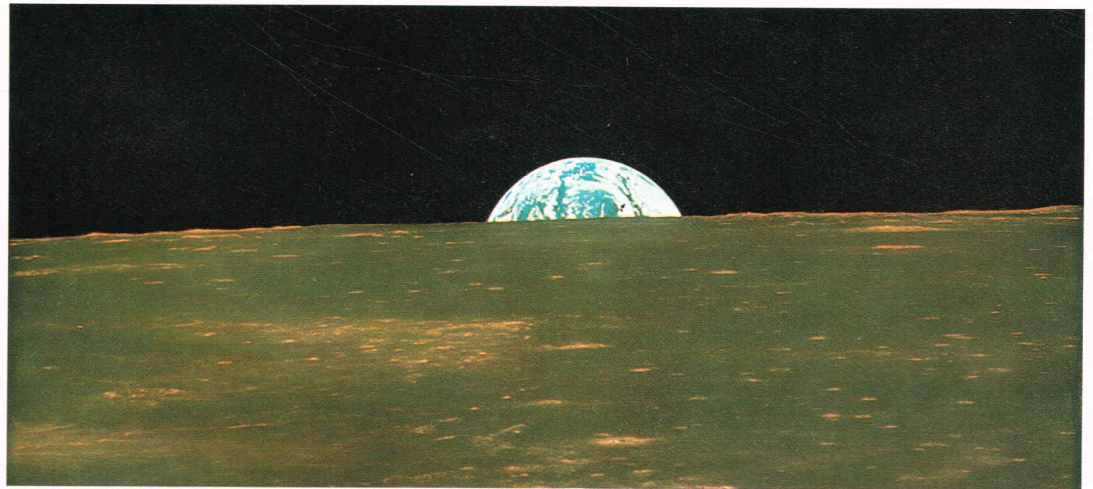
Photographs taken from high-flying rockets can show that the Earth's surface is curved, and during the past few years pictures taken from rocket vehicles many thousands of miles away from us have shown the Earth as it really is: a globe in space, shining because it reflects the light of the Sun. Men who have flown round the Moon have seen the Earth as a half

or a crescent, with many of the lands and seas hidden by masses of cloud in our atmosphere.

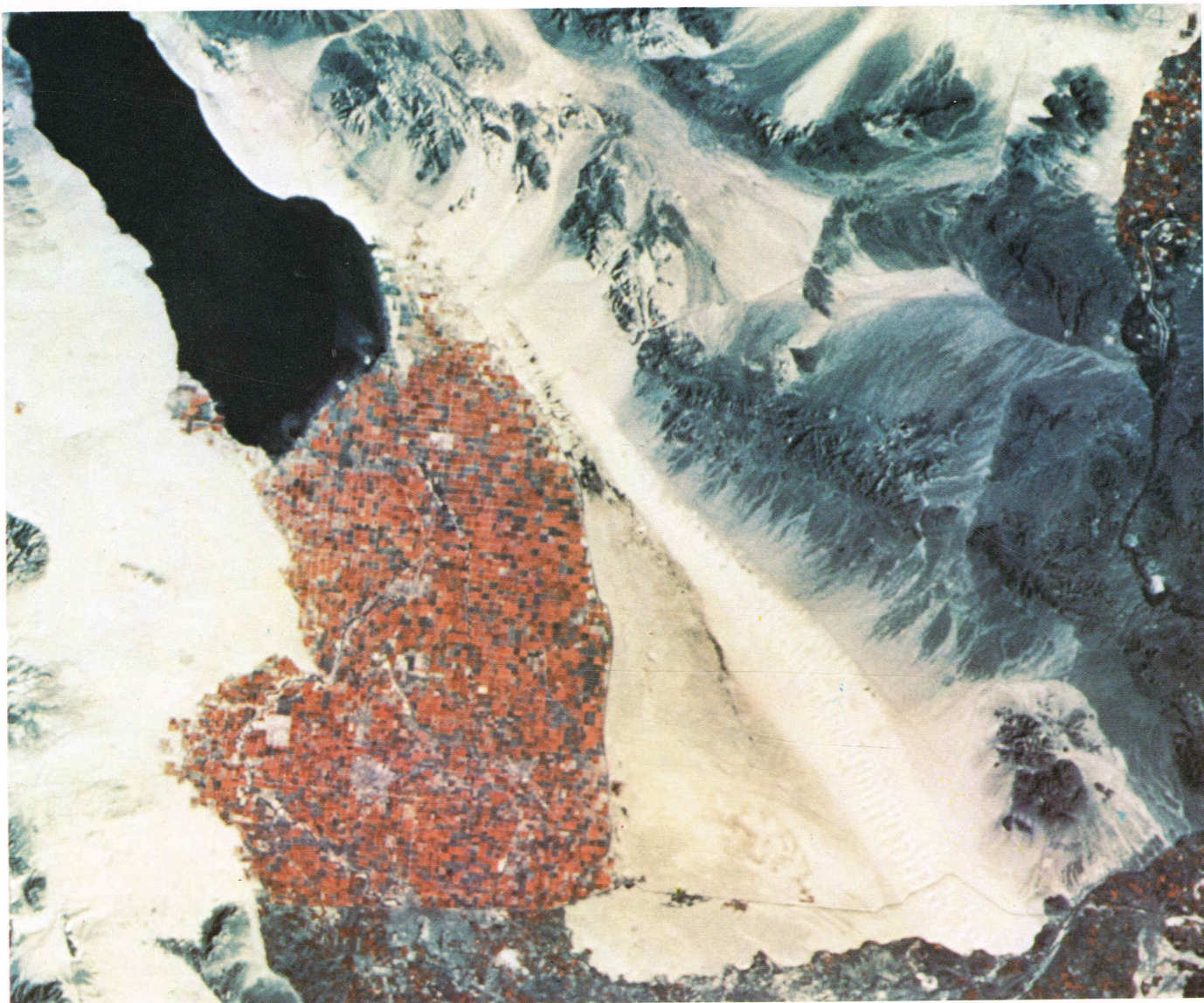
The Earth's distance from the Sun is 93,000,000 miles. This may sound a long way; but in astronomy one has to become used to tremendous distances and very long periods of time. The Sun is much larger than the Earth (in fact, its volume is more than a million times as great), and it sends us practically all our light and heat. Without it, we could not exist.

The Earth is spinning round, rather in the manner of a huge top, taking just under 24 hours to complete a full turn. This explains why we have regular 'day' and 'night'. Obviously, the Sun can shine on only one half of the Earth at any one time, so that half the Earth is in daylight while the other half is having its period of night. Because the Earth is spinning from west to east, the whole sky seems to move

Two photographs of the
Earth, as seen from an
Apollo spaceship
circling the Moon.







above: The Imperial Valley in California, USA, photographed from a spaceship going round the Earth. The film used was a special one to make vegetation show up red.

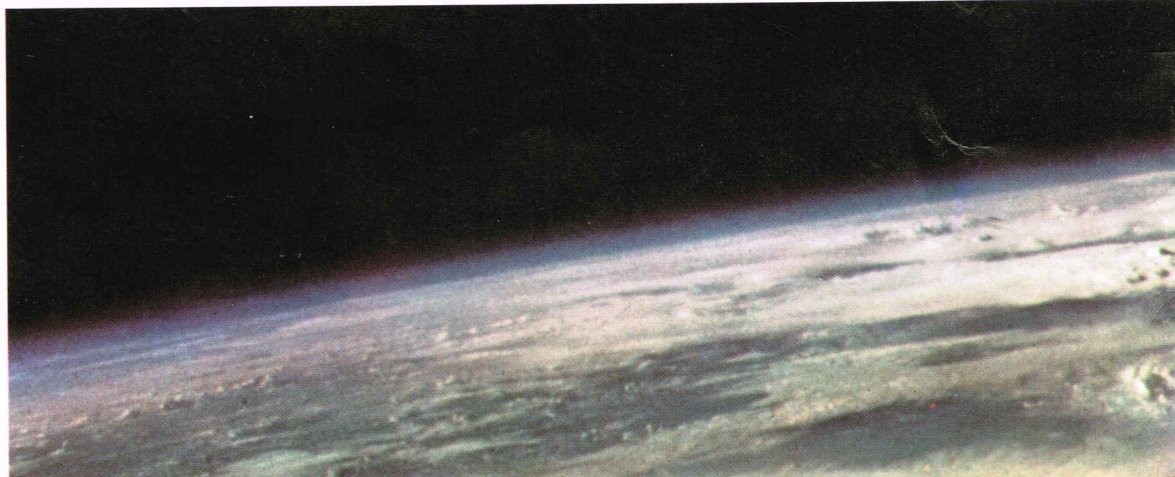
round from east to west, taking the Sun, the Moon and the stars with it. This is why the Sun seems to rise in the east and set toward the west.

The Earth's path round the Sun is known as its 'orbit'. The axis of rotation – that is to say, the imaginary line running through the north and south poles – is not perpendicular to the plane of the orbit; the Earth is 'leaning over' at an angle of $23\frac{1}{2}$ degrees, as shown in the picture. It is this tilt which is the cause of the seasons.

When the north pole is tipped toward the Sun, Britain has its summer, while it is winter in countries south of the equator such as Australia and New Zealand; when we are having our coldest weather, around Christmas-time, it is summer in the south. The Earth's orbit is not perfectly circular, and we are actually at our closest to the Sun in December!

The Sun is a star. It is no larger, hotter or more luminous than many of the stars you can see on any clear night; it appears

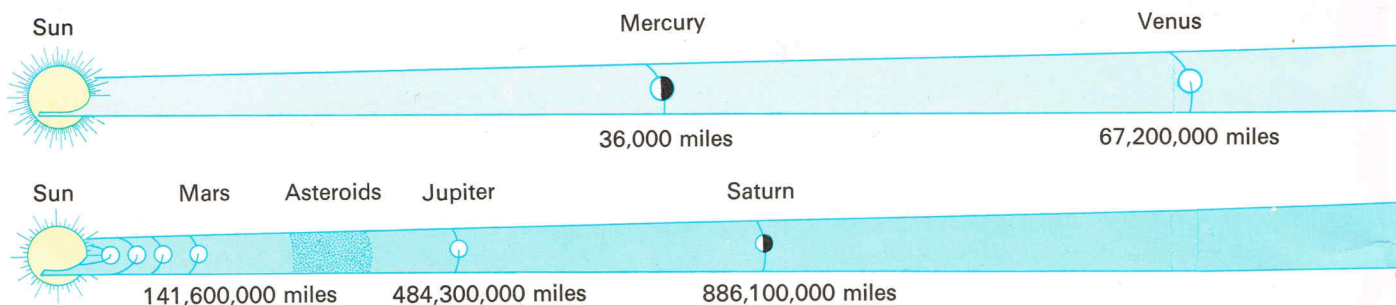
right: Part of the Earth, photographed from space. The curvature of the surface is clearly shown.





left: Part of
Ghana, in Africa,
photographed from a
spaceship more than
100 miles above the
Earth.





much more splendid than the rest simply because it is so much closer to us. It is the centre of a system of planets, of which the Earth is one. In order of distance from the Sun, the planets are: Mercury, Venus, the Earth, Mars, Jupiter, Saturn, Uranus, Neptune and Pluto.

It is very important to make sure of the difference between a star and a planet. Just as the Sun is a star, so the stars are suns; they are huge globes of gas, shining by their own light. The planets, on the other hand, have no light of their own, and depend upon reflecting the light of the Sun. They look like stars, and some of them are very brilliant; but they are our nearest neighbours in space, and they are

not nearly so important as they seem.

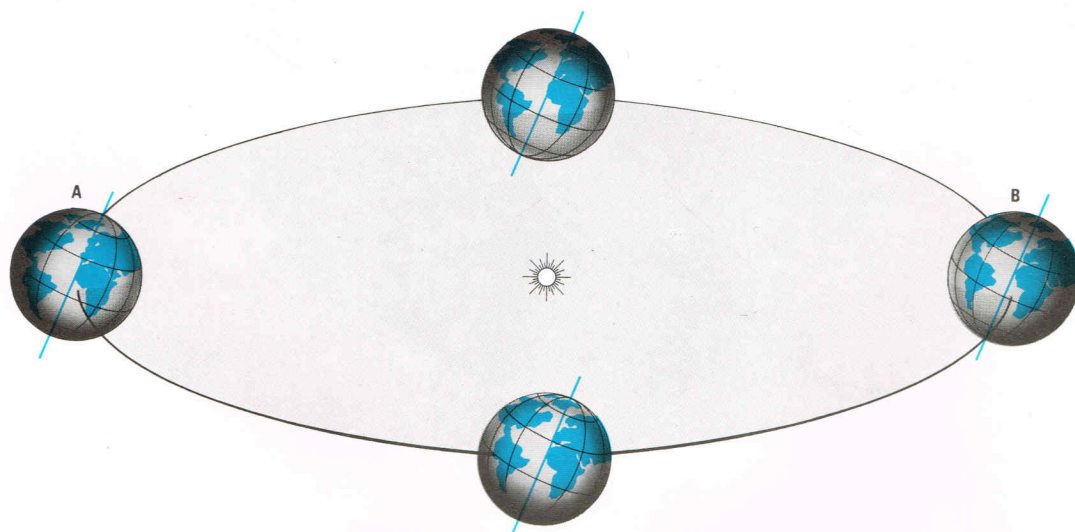
As the diagrams will show, the family of planets – known as the Solar System – is divided into two parts. There are four comparatively small worlds with solid surfaces (Mercury to Mars), beyond which come four much larger planets made up chiefly of gas. Jupiter and Saturn are the giants of the Solar System, even though they are very small compared with the Sun.

What, then, of the Moon? It seems brilliant in our skies, but it is a very unimportant body in the universe. It keeps company with us in our never-ending journey round the Sun, and is known to astronomers as the Earth's 'satellite'.

below: The Earth's axis is tilted by $23\frac{1}{2}^\circ$. The diagram to the right shows the seasons. At position A the Earth's north pole is tilted towards the Sun, and it is summer in the northern hemisphere; at B it is summer south of the equator.



below: The sizes of the planets and the Sun, which can only be partly shown.



Mercury

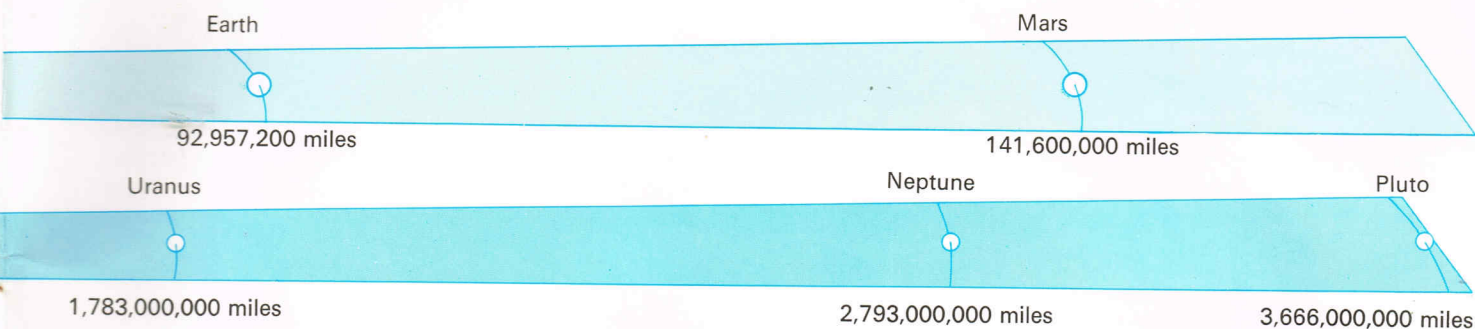
Venus

Earth

Mars

Jupiter

Saturn



Other planets, too, have satellites: Jupiter has as many as twelve, two of which are considerably larger than our Moon.

The stars are not fixed in space. They are moving about in all kinds of directions, at very high speeds; but they are so far away from us that they do not seem to shift much in relation to each other, and the star-patterns or 'constellations' that we see today are almost the same as those that must have been seen by our cave-dwelling ancestors. The farther away an object lies, the slower it seems to move. The planets, however, are much nearer to us than the stars, and seem to shift about from constellation to constellation. This was first discovered thousands of years ago; the word 'planet' really means 'wandering star'. Of the planets, Venus, Mars, Jupiter and Saturn appear very brilliant. Venus can often be seen with the naked eye while the Sun is still above the horizon, whereas the stars are completely overpowered by the brightness of the sky.

The distances of the stars are measured in millions of millions of miles. Distances of this kind are not easy to appreciate, and perhaps the best way is to give a scale model. As we have seen, the distance between the Earth and the Sun is 93 million miles; let us represent this by one inch. On the same scale, the nearest star will then be more than four miles

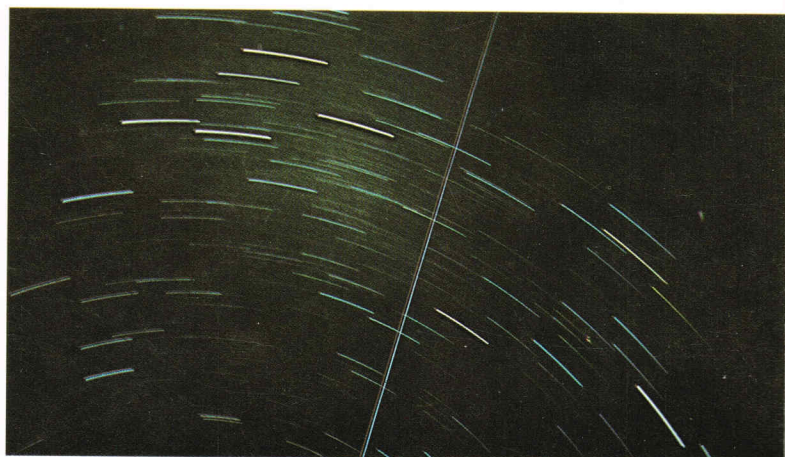
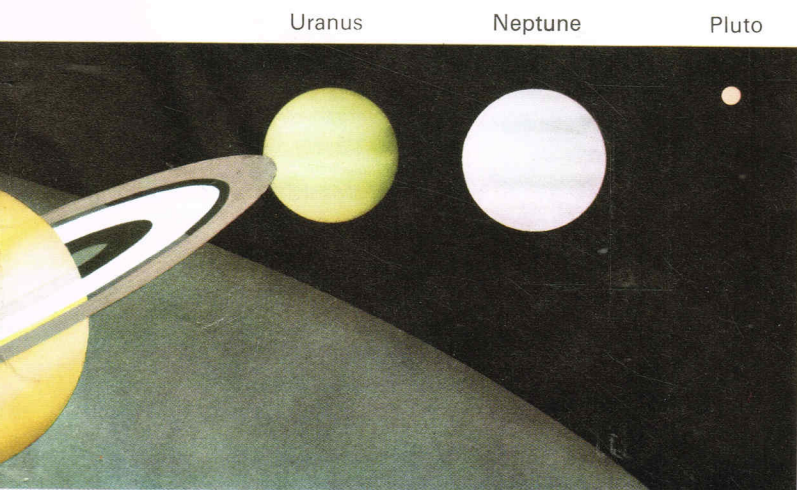
away. The Solar System is very isolated in space. Rockets have taken men to the Moon, and have sent scientific instruments out to the planets Mars and Venus; but we cannot hope to build rockets which will take us to the stars.

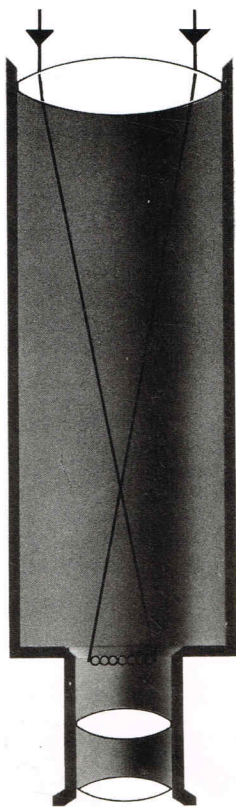
The idea of flying to the Moon is very old, and stories about it were written hundreds of years ago. However, it is a very difficult matter. The Earth has a very strong pull of gravity, which is why we feel 'heavy'. A spaceship has to break free from this gravitational pull, and to do this it must work up to a speed of 7 miles per second, which is about equal to 25,000 miles per hour. Also, we must remember that the Moon is almost a quarter of a million miles away, and that the Earth's air does not stretch upward for very far. Mountaineers who have reached the top of Everest cannot breathe without special masks, because the air there is too thin; and Everest is only about 5 miles high. Most of a journey between the Earth and the Moon has to be done in empty space.

Ordinary flying machines, such as aircraft, cannot work unless there is air around them. The only machine that can work in empty space is the rocket, which does not depend upon atmosphere. A modern rocket is very powerful indeed – and also very large. The vehicle which launched the Apollo spaceship which sent

above: Distances of the planets from the Sun. The upper diagram shows the inner planets (Mercury to Mars); the lower diagram, drawn to a much smaller scale, shows the entire Solar System.

below: Star trails. Because of the Earth's rotation, each star is shown as a line of light. The streak crossing from top to bottom is the trail left by a meteor.





above: How the refracting telescope works. The light is collected by the object-glass at the top, and brought to focus at the bottom, where the eyepiece is placed.

the first men to the Moon, in July 1969, stood more than 360 feet high.

Before we can send men to more distant worlds, such as the planets Mars and Venus, we must develop still more powerful rockets. This will certainly be done in the future, but for the moment only the Moon is within our reach. Meanwhile, astronomers on Earth are doing all they can to find out more about the planets, so that the first men to go there will know what to expect.

The most important part of the astronomer's equipment is his telescope. Astronomical telescopes are of two kinds: refractors and reflectors. With a refractor, the light from the object to be studied is collected by a specially-shaped lens known as an object-glass; the reflector has no

object-glass, but collects the light by means of a curved mirror. The world's largest telescope, the Hale reflector at Palomar in California, has a mirror 200 inches across. Many of the photographs in this book were taken with the Hale telescope.

Light is a wave-motion. It travels at a tremendous speed, covering 186,000 miles every second; even so, it takes a ray of light over 4 years to reach us from the nearest star. Longer wavelengths cannot be seen, because they do not affect our eyes, but they can be collected by special instruments called 'radio telescopes'. The most famous radio telescope can be seen at Jodrell Bank, in Cheshire; it has a metal dish 250 feet across. It does not produce a visible picture, and one cannot



right: The great 200-inch Hale reflecting telescope at Palomar, California. Primary Mirror (1); Observer's cage (2); the Cassegrain focus (3); Coudé focus (4); southern end of the Polar Axis (5); Coudé and Cassegrain Secondary Mirror (6); Right Ascension Drive (7); Declination Axis (8); Dome Shutter (opening 30-ft) (9); Dome (137-ft diameter) (10); Primary focus (54-ft) (11); Northern Pillar (12); Southern Pillar (13); Control Panel (14).

look through it, but it can provide us with information which we could never obtain in any other way.

There is one thing to remember. Though modern large telescopes are very expensive indeed, you do not need a large telescope to start taking a real interest in astronomy. There is a great deal to be seen even with the naked eye; you can learn the star-patterns, watch the moving planets, and make out the light and dark patches on the Moon. If you can buy or borrow a pair of binoculars, you will be able to see the Moon's mountains and craters clearly, and you will also find many wonderful clusters and groups of stars. Astronomy is one of the most fascinating of all hobbies, and there is always something new to see in the sky.



left: The dome covering the 24-inch refracting telescope at Flagstaff, Arizona.

below: The 250-foot radio telescope at Jodrell Bank, Cheshire



2 Find Your Way Round the Sky

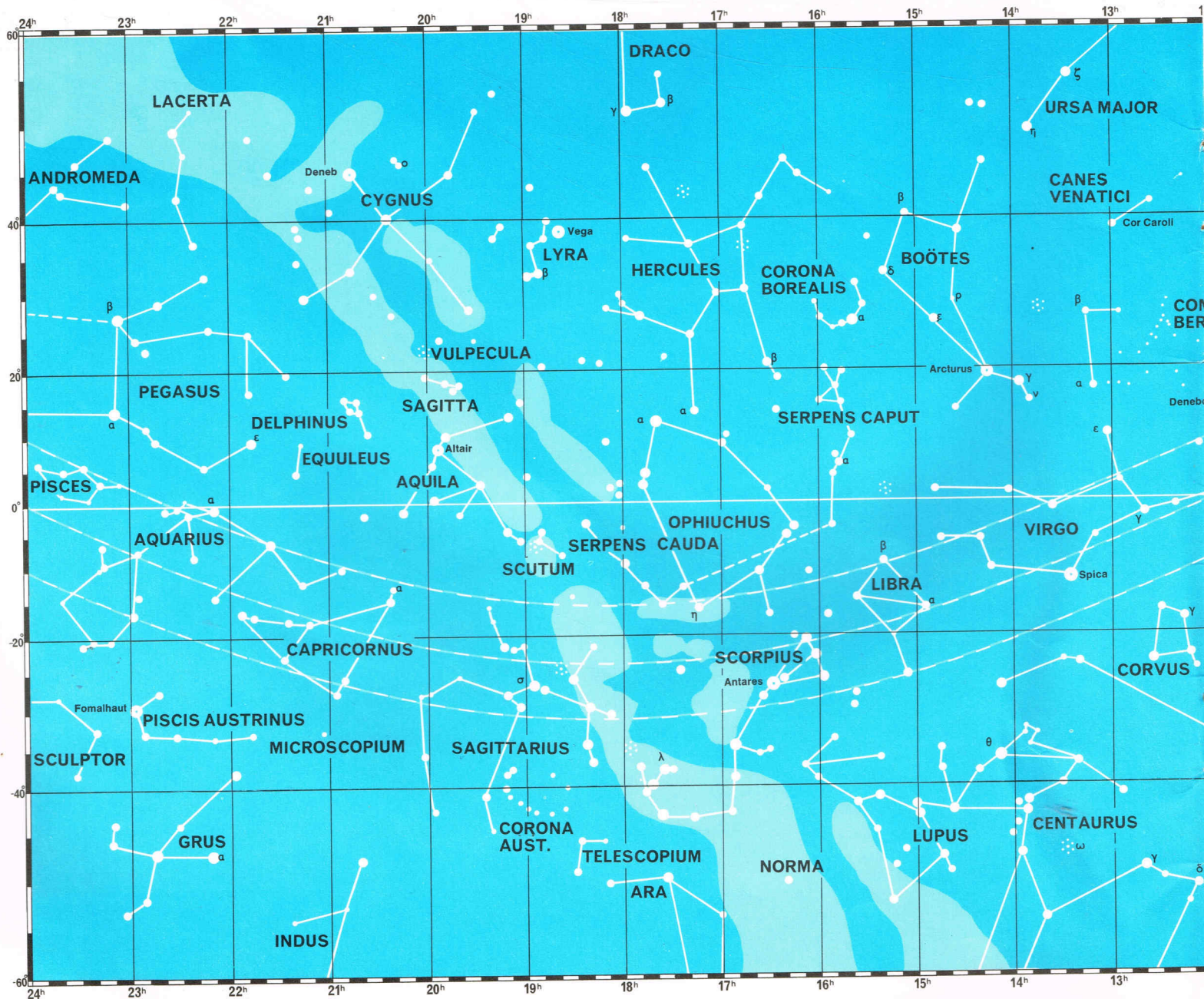
How many stars can you see on a dark, clear night? Many people will say 'Millions', but in fact nobody can ever see as many as 3000 stars at one time without optical aid. Of course, binoculars will show many more, and when a telescope is used the number of stars visible becomes so great that it would be quite impossible to count them. Our star-system, known as the Galaxy, contains a total of more than 100,000 million stars, each of which is a sun in its own right.

The map on this page shows many of the constellations, which, as we have seen, look the same year after year, because the stars are so far away from us that they seem to keep in almost the same relative

positions. A list of the constellations is given on page 46. Because Latin is still the international language (even though nobody actually speaks it now), the constellation-names are usually written in Latin: thus the Dragon is 'Draco', the Bull is 'Taurus', the Swan is 'Cygnus', and so on.

Star recognition is not nearly so difficult as might be thought. The best method is to select a few of the most prominent groups, and use them as guides to the rest. For instance, Orion, the Hunter, is on view during winter evenings (look toward the middle of the map on page 13). In it are two very brilliant stars, Betelgeux and Rigel. The three stars between Betelgeux and Rigel make up the Hunter's Belt, and

Map of the stars. The light regions indicate the Milky Way. The curved dotted lines mark the region of the ecliptic, in which the Sun, Moon and planets are always to be found.



serve as a useful pointer; downwards they show the way to Sirius in Canis Major (the Great Dog), while in an upward or northerly direction they point to Aldebaran, a bright red star in Taurus (the Bull). The maps given here should be quite good enough to help in finding out which constellation is which.

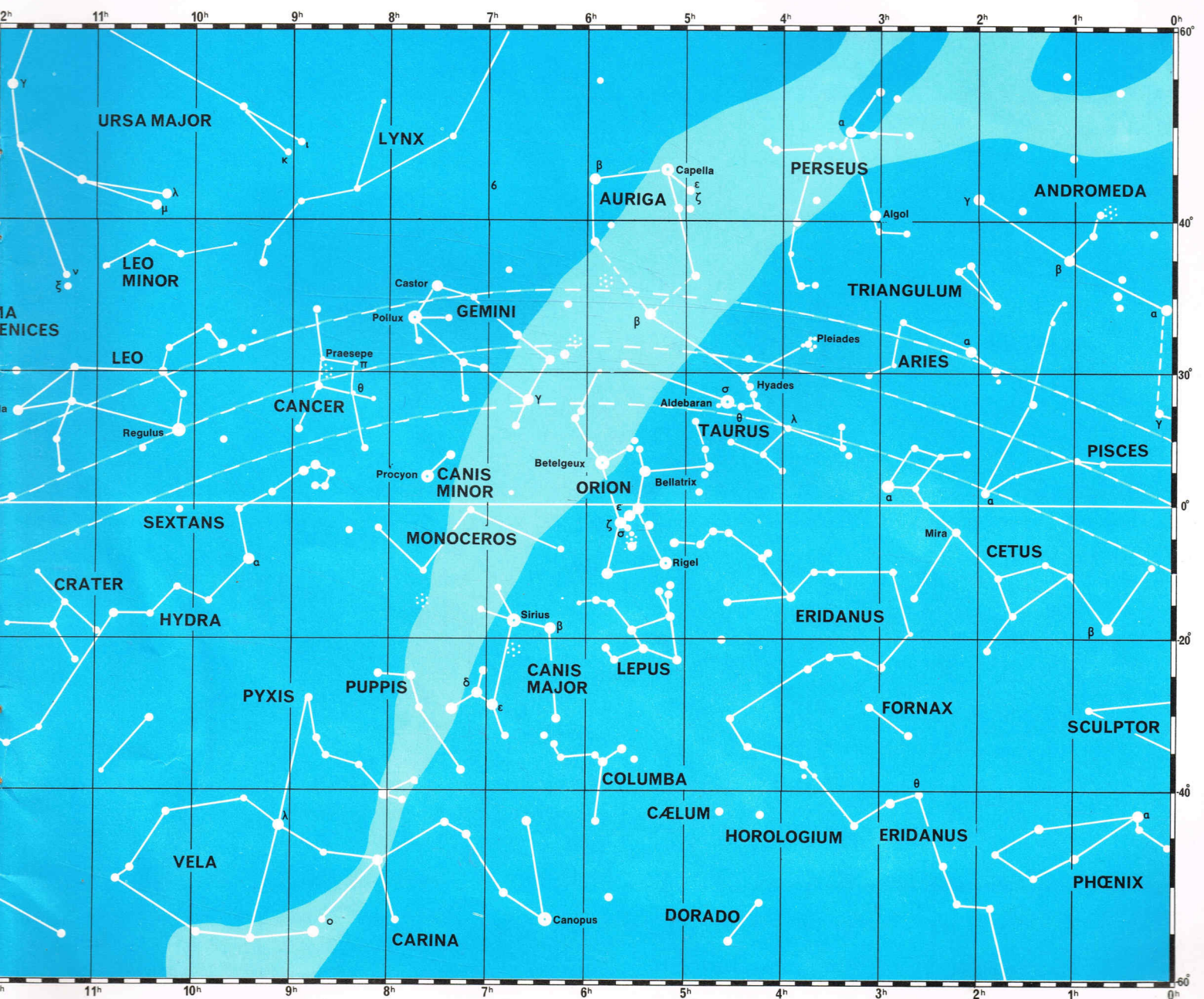
However, Orion is not always visible. During summer evenings, for instance, it cannot be seen at all, because the Sun lies too close to it in the sky – and for obvious reasons, stars cannot be seen in the daytime; there is much too much light! On the other hand, summer groups such as Scorpius (the Scorpion) cannot be seen in the winter.

Now let us turn to the maps on pages 14 and 15, which show the constellations visible at any time of the year. The left-hand charts of each pair show the view 'looking south', while the right-hand charts show the view 'looking north'. For instance, suppose you want to find out

what can be seen in the evening on November 15? Look at the bottom pair of charts on page 15 – and you will be able to tell that Orion is rising in the south-east, while Ursa Major (the Great Bear, containing the Plough) is rather low down in the north.

The Great Bear is one of the most famous of all the constellations. From Britain it never sets, so that you can always see it whenever the sky is clear and dark. Sometimes it appears almost overhead; at other times it can be seen fairly close to the northern horizon. Two of its stars, the 'Pointers', show the way to the Pole Star. The second star in the Bear's tail is called Mizar; it is interesting because it has a much fainter star, Alcor, close beside it.

Another well-known constellation is Cassiopeia, whose chief stars are arranged in the form of a rough W or M. To find Cassiopeia, draw an imaginary line from Mizar through Polaris, and continue it



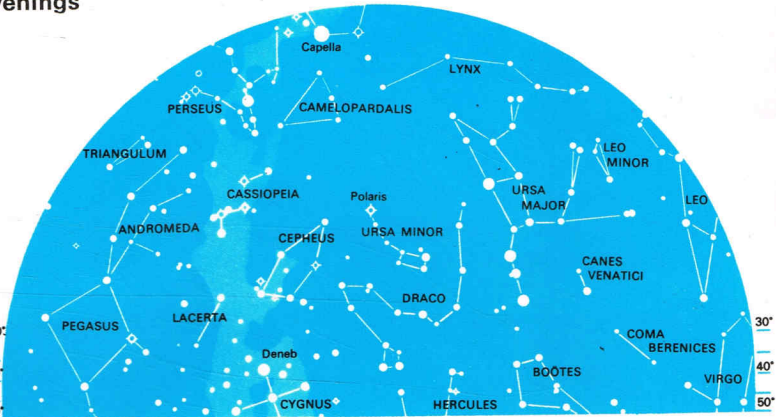
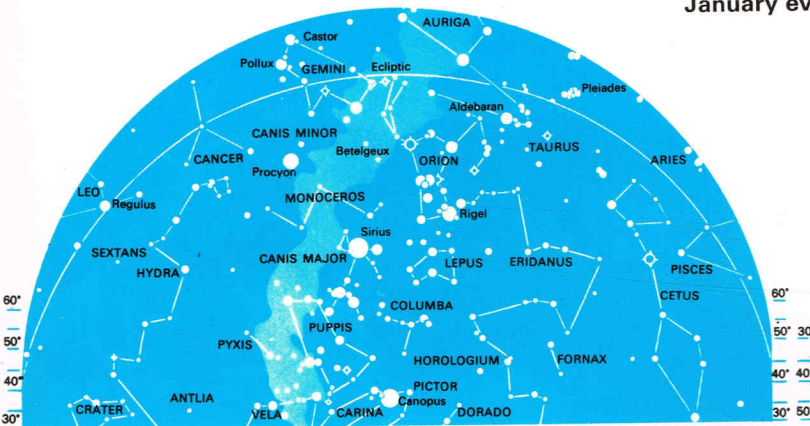
until you come to the W. Like the Great Bear, Cassiopeia never sets over Britain – though if you happen to go to Australia or New Zealand you will be unable to see it at all, because from these southern countries Cassiopeia never rises.

The names of the constellations are very old. Ptolemy, a famous astronomer who lived as long ago as the year 150, gave a list of 48 groups, all of which are still to

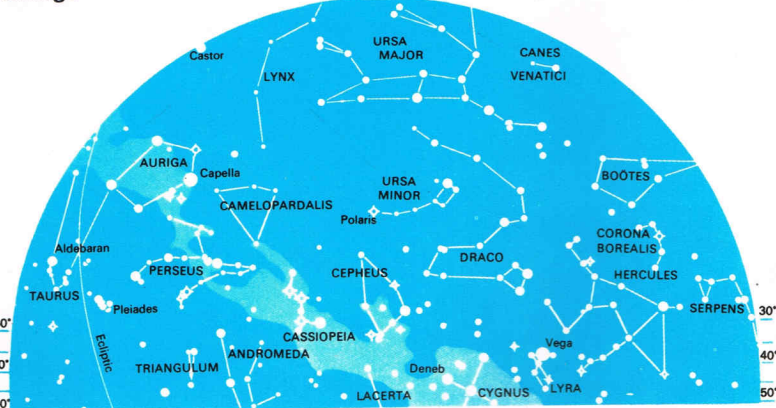
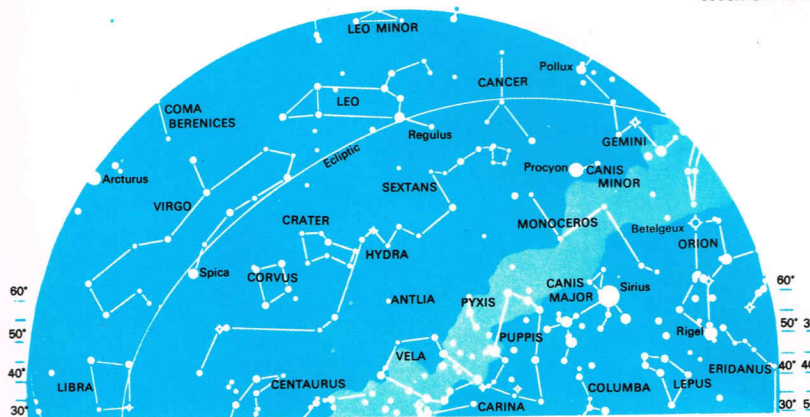
be found on our maps – though the list has been extended since, and some of the constellation-names are much more modern. Ptolemy's names were drawn largely from legend and mythology, and it has been said that the sky is a real picture-book. Orion was a famous hunter, who boasted that he could kill any creature on Earth, but was fatally wounded by a scorpion (Scorpius). Leo

The stars visible at different times of the year.

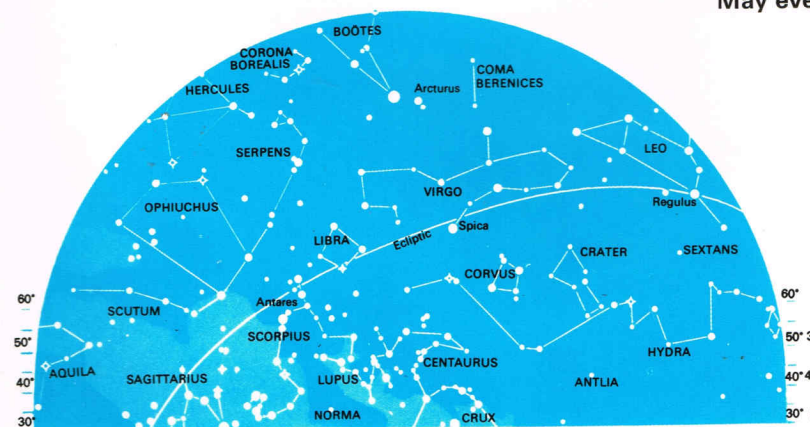
January evenings



March evenings



May evenings

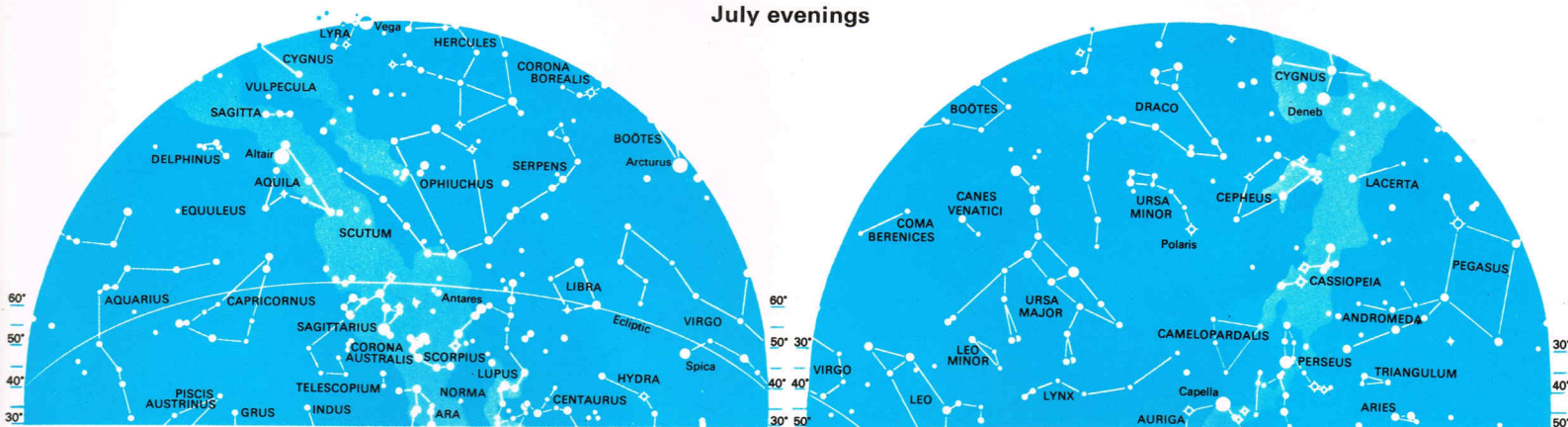


was a fierce lion, eventually killed by the hero Hercules; Andromeda was a princess who was chained to a rock to be eaten by a sea-monster, but was rescued in the nick of time by another brave hero, Perseus. We also find living creatures, such as the Lynx, and more everyday objects such as Triangulum (the Triangle). It cannot honestly be said that the constellation-outlines have any resemblance

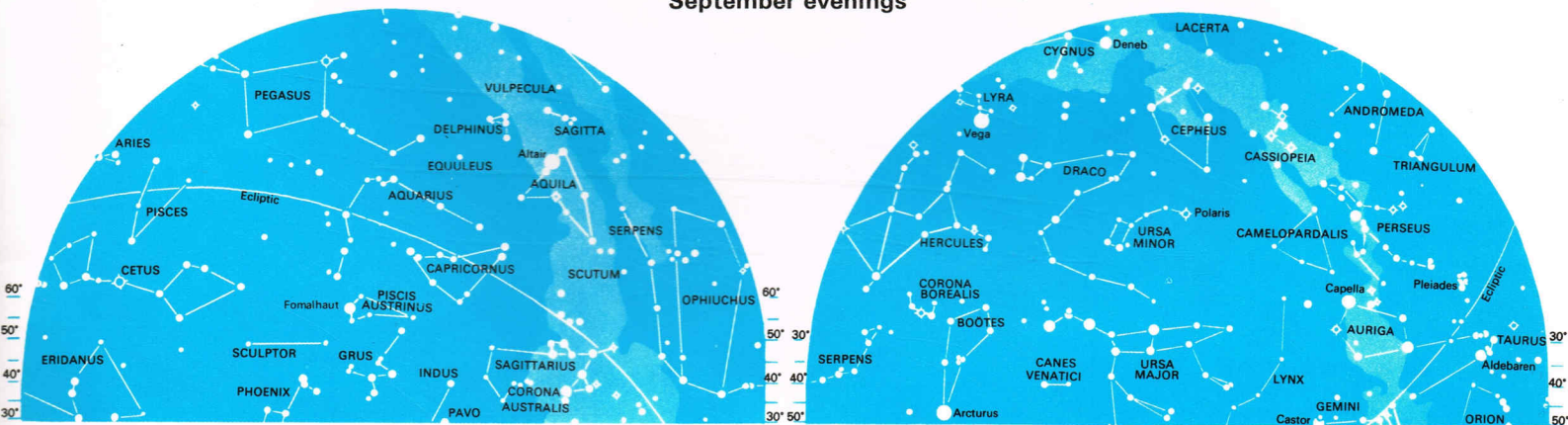
to the objects after which the groups are named, but the system has been in use for so long that it will never be altered now. Astronomers have become accustomed to it.

Some of the bright stars have individual names. In Ursa Major, for example, the two Pointers to Polaris, the Pole Star, are named Merak and Dubhe. Polaris, in Ursa Minor (the Little Bear), is a special

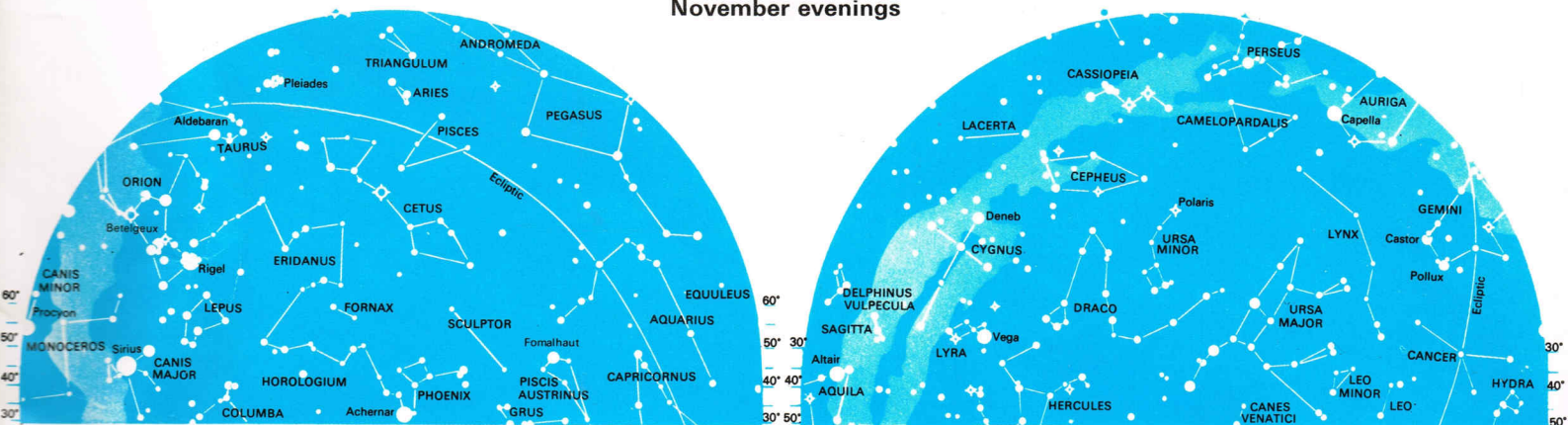
July evenings



September evenings



November evenings



star, because it happens to lie in the northernmost position in the sky. This is why Polaris seems to stay almost still, while everything else moves round it once a day. Of course, this motion too is due entirely to the Earth's daily spin on its axis, and Polaris is not genuinely important, though it is much larger and hotter than our Sun.

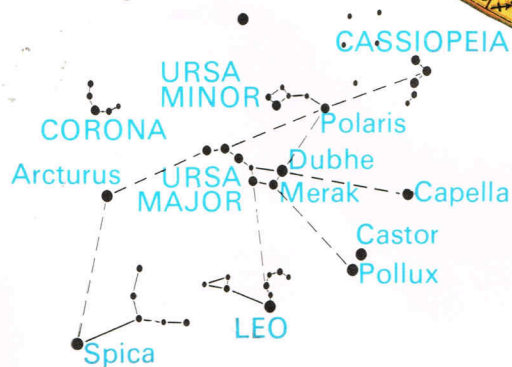
Of the brilliant northern stars, three are particularly worthy of mention. Arcturus, which can be found by following round the curve of the Great Bear's tail (see the

diagram on page 16) is distinctly orange; it is below the horizon during winter evenings, but is very striking in spring and summer. Capella, in Auriga (the Charioteer), is yellow, and almost overhead during winter evenings. On summer evenings, however, Capella is very low in the north, and the overhead position is taken by an equally bright star, the blue Vega in Lyra (the Lyre or Harp), shown in the diagram on page 17. Two more bright stars, Deneb in Cygnus (the Swan) and Altair in Aquila (the Eagle), make up a

Old charts of the sky, showing the constellation figures.
left Northern sky.
right Southern sky.



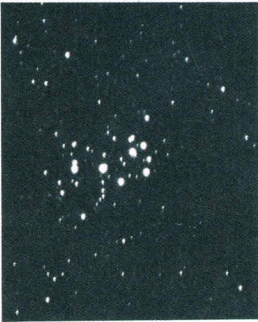
below: Ursa Major (the Great Bear) and its surroundings.



It has often been said that 'the sky is a picture-book'. In a way this is true, as can be seen from the old maps given on this page. Many of the ancient Greek legends are re-told in the heavens. For instance, there is the legend of Perseus and the princess Andromeda; there are, too, Castor and Pollux, the 'Twins', who are represented by two bright stars side

A star map of the Northern Hemisphere. Constellations shown include Taurus (top left), Cepheus (top center), Cygnus (center left), Lyra (center right), Ursa Major (top right), Altair (bottom center), and Scutum (bottom right). Stars labeled include Deneb (Cygnus), Vega (Lyra), Altair (Scutum), and η (Scutum). A dashed line connects Deneb to Vega.

3 Signposts in the Sky



above: The star-cluster of the Pleiades.

Of all our 'signpost' constellations, three are of particular use. Throughout the year we have Ursa Major, in the northernmost area of the sky. During autumn we have Pegasus, the Flying Horse, whose chief stars outline a square. And in winter there is Orion, shining down so brilliantly that he cannot be mistaken.

All the leading stars of Orion are bright. Betelgeux, in the upper left of the constellation, is orange-red, while Rigel, to the lower right, is glittering white. The stars of the Belt point upward to a lovely star-cluster, the Pleiades or Seven Sisters; to the opposite side of the Belt there lies Sirius, which is one of the nearest of all the stars, and is outstandingly bright. Sirius, like Rigel, is white; but from Britain it is never very high above the horizon, so that it twinkles violently, and seems to flash red, blue and green. Star-

twinkling is purely an effect of the Earth's unsteady air. When a star is high in the sky, it twinkles much less than when it is low down.

If you have a pair of binoculars or a small telescope, look at Orion's Sword, just below the Belt. In it there is a patch of gas, known as a nebula. It is a wonderful sight – and it is of special interest to astronomers, because we believe it to be one of the regions in which fresh stars are being born.

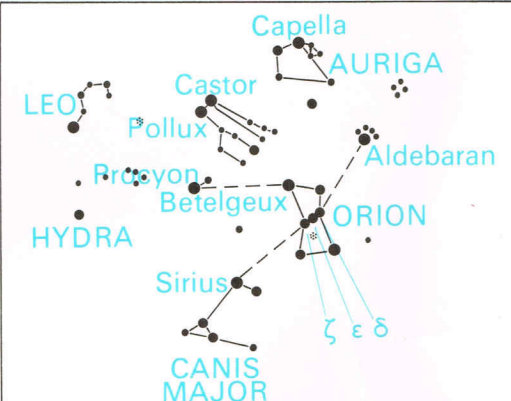
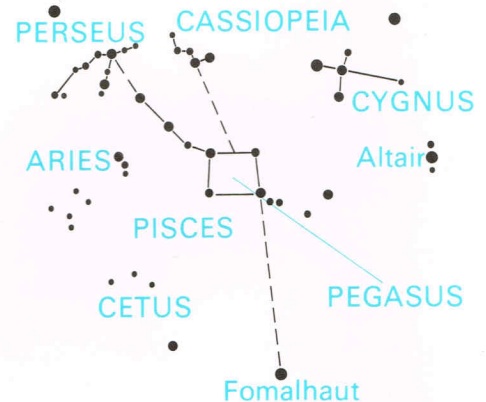
If you draw an imaginary line from Rigel through Betelgeux, and continue it upward, you will come to two rather bright stars side by side. These are Castor and Pollux, the Twins (in Latin, Gemini).

Of the two, Pollux is rather the brighter. If you have a pair of binoculars you will be able to see that while Pollux is rather orange in colour, Castor is

below: The gas and dust nebula in Orion.



below: The square of Pegasus; how to find Fomalhaut and Perseus.



above: How to find bright stars surrounding Orion.

white. This shows that the surface of Castor is the hotter of the two. It is interesting to note that the Twins are not really close together; Castor is much the further away from us, and simply happens to lie in almost the same direction as seen from Earth. There are some other fairly bright stars in Gemini; and below lies Procyon, a brilliant star in the constellation of Canis Minor (the Little Dog).

Next to Gemini we see a much fainter constellation, Cancer (the Crab). Here there are no bright stars, but there is one very interesting object, the star-cluster known as Præsepe (nicknamed the Beehive). It is made up of a mass of dim stars. To the naked eye it appears as a misty patch, but a small telescope will show many separate stars in it. And beyond Cancer comes Leo, the Lion, with one particularly bright star, Regulus.

All these are shown in the diagram, but there is another way to find Regulus. Go back to the Great Bear (Ursa Major), and use the two Pointers 'the wrong way' – that is to say, away from Polaris. You will come to Leo; Regulus lies at the bottom end of a curved line of stars which is often called the Sickle. The rest of Leo is made up of a triangle of stars, bright enough to be easily found.

The Great Bear itself is a 'signpost' just as useful as Orion. Follow round the curve of the tail, and you will reach a really brilliant star, Arcturus in the constellation of Boötes (the Herdsman). It is not always visible, but it is very striking during evenings in spring and all through the summer. It is pale orange in colour, and is about as bright as the yellow Capella, which is almost overhead in winter evenings. Between Arcturus and the Great Bear is the little constellation of Canes Venatici (the Hunting Dogs), also shown in the diagram.

Follow round the curve from the Great Bear through Arcturus, and you will reach Spica, a bright white star in the constellation of Virgo (the Virgin). It is well south of the equator of the sky, and so is not visible in winter evenings, but it comes into view during the late spring. Virgo is a very large group, and contains many objects of interest, even though Spica is its only brilliant star. The curved line of stars between Spica and Leo is a region which is very rich in faint star-systems, one of which is called the Sombrero Hat (though astronomers prefer to know it by its catalogue number of M.104). When photographed through a large telescope the Sombrero Hat is a

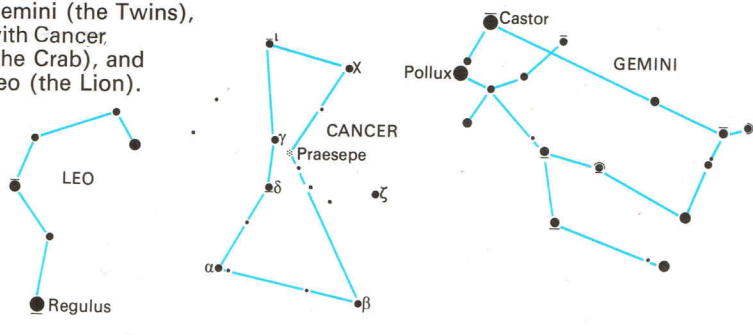


left: The Sword of Orion. The nebula lies in the middle.

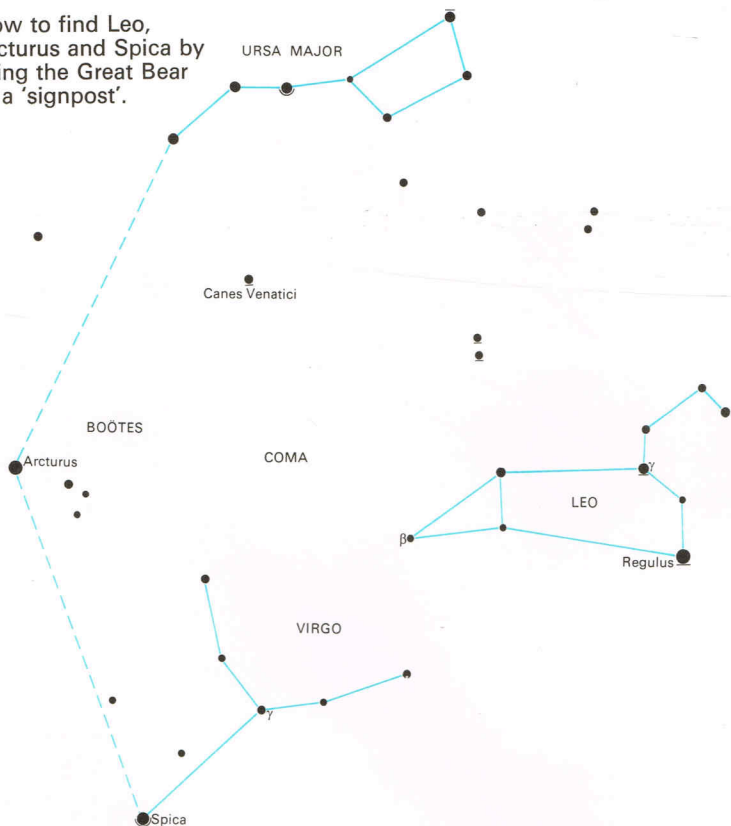


below: The Horse's Head nebula in Orion.

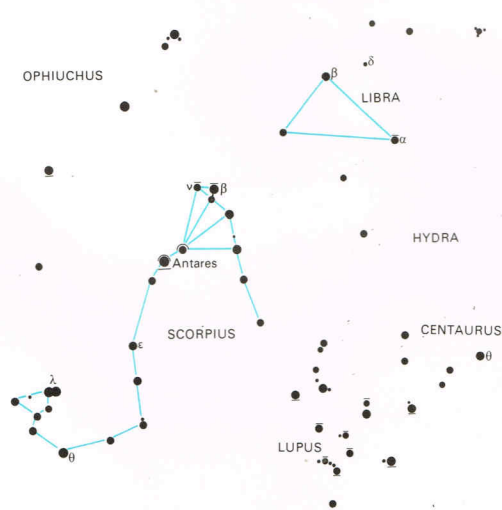
Gemini (the Twins),
with Cancer
(the Crab), and
Leo (the Lion).



How to find Leo,
Arcturus and Spica by
using the Great Bear
as a 'signpost'.



Scorpius and Libra,
two groups visible low
in the south during
summer evenings.



lovely sight, as the photograph shows. Unfortunately it is too dim to be seen in a small telescope. It is so far away that its light, travelling at 186,000 miles per second, takes 41 million years to reach us – so that we are now seeing it not as it is today, but as it used to be 41 million years ago. If a star inside it exploded, we would not know for another 41 million years in the future.

During summer evenings Orion is below the horizon, but other bright constellations come into view. One of these is Scorpius, the Scorpion, which is always rather low down as seen from Britain. Its leading star, Antares, is red in colour, and is extremely large. Its diameter is over 200 million miles, so that it could contain the whole orbit of the Earth round the Sun. Next to Scorpius is a much fainter group, Libra (the Scales).

Both Scorpius and Libra belong to the Zodiac. The Zodiac is a belt stretching all the way round the sky, in which the Sun, Moon and bright planets are always to be found. It is made up of twelve constellations: Aries (the Ram), Taurus (the Bull), Gemini (the Twins), Cancer (the Crab), Leo (the Lion), Virgo (the Virgin), Libra, Scorpius, Sagittarius (the Archer), Capricornus (the Sea-goat), Aquarius (the Water-bearer) and Pisces (the Fishes). Not all the Zodiacal constellations are bright, but all can be found by looking at the star-maps given in this book. If you see a bright object in a Zodiacal constellation which is not to be found on the star-maps, you may be sure that it is a planet. For instance, during the winter of 1970 Jupiter is in Libra, while Saturn is near the border of Aries and Pisces. You can never see planets in other parts of the sky, so that, for example, no planet ever lies in the region of the Great Bear. During a year, the Sun passes all the way round the Zodiac.

For most of the year the Milky Way is a glorious sight. It runs through Gemini, Cassiopeia and the prominent summer constellation of Cygnus (the Swan), but it is at its brightest in the region of Scorpius and the nearby group of Sagittarius (the Archer). Any small telescope is enough to show that the Milky Way is made up of stars. It also contains some gas-patches known as nebulae, though not many of them are bright. One particularly beautiful gas-patch is the Omega Nebula, which lies near the boundary of Sagittarius.



left: The Omega Nebula,
a gas cloud.



below: The Sombrero
Hat, a separate galaxy
far beyond the Milky
Way system.

4 Stars of Different Kinds

No telescope is powerful enough to show a star as anything but a point of light. If you see a star as a large, fuzzy ball, you may be sure that your telescope is out of adjustment. Yet not all stars are similar; and in particular, they are of different colours. Thus Betelgeux and Aldebaran are orange-red, while Capella is yellow, Rigel and Sirius are white, and the stars in the lovely cluster of the Pleiades or Seven Sisters are bluish.

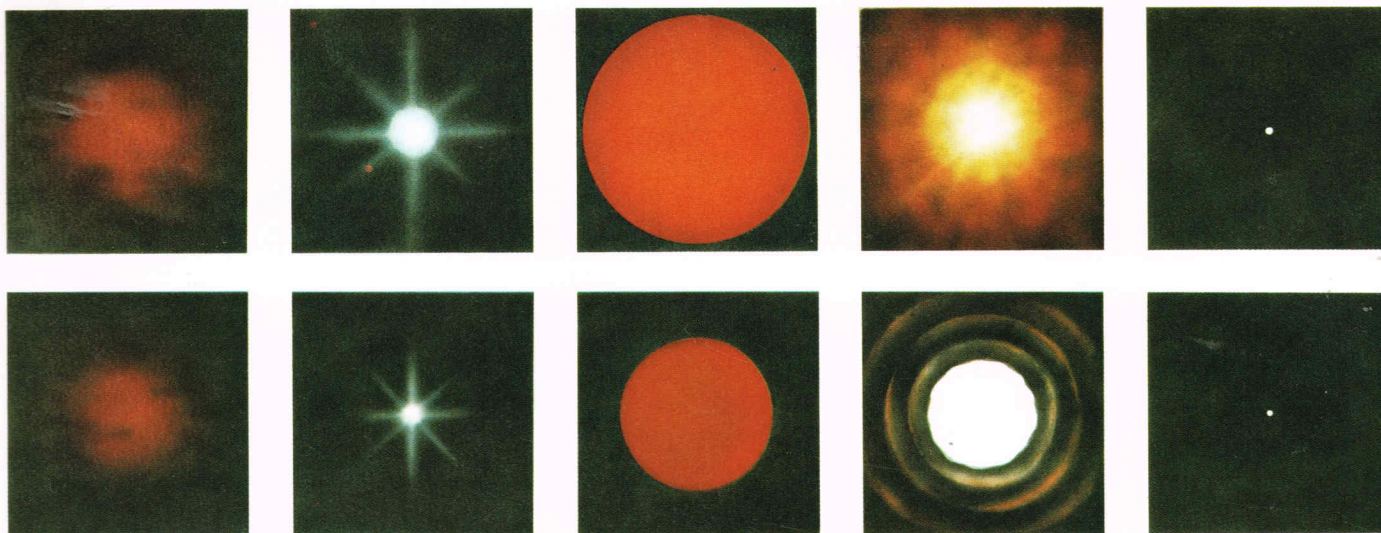
These differences are due to differences in surface temperature. The order is: blue, white, yellow, orange, red – so that our own yellow Sun, with its temperature of 6,000 degrees Centigrade, is hotter than Betelgeux, but much cooler than Rigel. To make up for its coolness, however, Betelgeux is very large. Its diameter is about 250 million miles, though, as with all red giant stars, it is much less

dense than a star such as the Sun.

Using special instruments, astronomers have been able to find out how the stars shine. They are not burning, in the manner of coal fires; instead, they are producing their energy by changing the materials deep inside their globes. Normal stars contain large amounts of one particular gas, hydrogen. Near their centres, where the temperatures are colossal (some 14 million degrees Centigrade in the case of the Sun), the hydrogen is being changed into another gas, helium. Each time a little hydrogen is changed into a little helium, energy is released; and it is this energy which keeps the stars shining. As they radiate, the stars are losing 'weight'. Each second of time, the Sun loses 4 million tons – but there is so much material left that the Sun will not change much for the next 6,000 million years.

The Lagoon Nebula in Sagittarius (the Archer), easily visible in binoculars.





It is thought that a star begins its career inside a patch of gas known as a nebula. Nebula is the Latin word for 'cloud', and nebulae are common in the sky; the most famous lies in the Sword of Orion, and is easily visible with binoculars (see the photograph on page 19). As the material collects together, the star shrinks and becomes hot. As soon as the temperature is high enough, the hydrogen-into-helium process begins, and the star settles down to a long period of steady shining.

First, let us follow the career of a modest star such as the Sun. It goes on radiating for thousands of millions of years, but at last its supply of hydrogen 'fuel' begins to run low, and it has to rearrange itself. What happens is that the inner core shrinks, while the outer layers swell out and become cool. The star becomes a red giant, and for a period it gives out a tremendous quantity of light and energy. Then, when all its fuel is exhausted, it collapses into a small, very dense star known as a white dwarf.

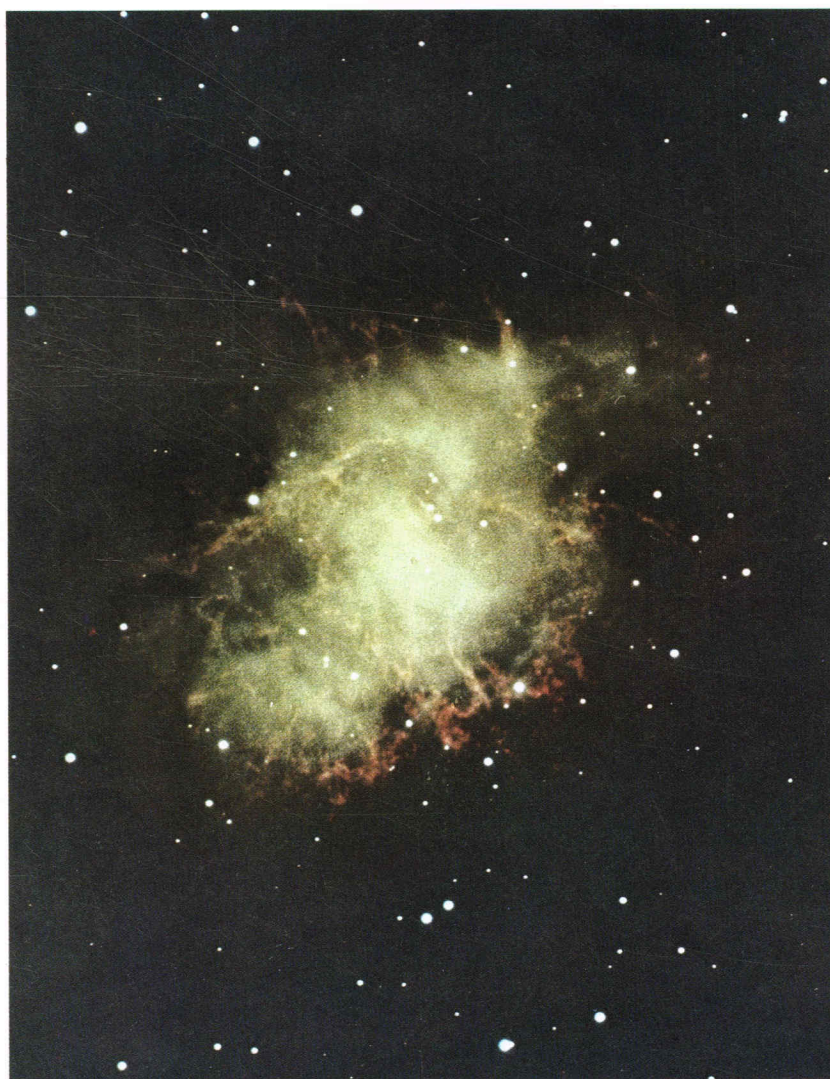
A larger, more massive star may have a much more spectacular end. It may 'blow up', so to speak, and send its material outward in all directions, leaving a patch of expanding gas. This is known as a supernova outburst. We can see some gas-clouds of this kind; the most famous is the Crab Nebula, in Taurus (the Bull), which we know to be the remains of a supernova which was seen by Chinese astronomers in the year 1054. For some months at that time the supernova was bright enough to be visible in broad daylight.

There are stars of all kinds. We find double stars, such as Mizar in the Great Bear; there are variable stars, which brighten and fade over short periods;

there are giants, dwarfs, and real 'search-lights' – such as a star known as S Doradûs, which is a million times as powerful as the Sun, and yet is so far away that it is invisible with the naked eye. But all stars have one thing in common: they cannot exist for ever. In the far future, our Sun too must die, and all life on Earth will come to an end.

above: upper The life-story of a star such as the Sun.
lower The life-story of a very massive, luminous star.

below: The Crab Nebula: the remains of a star which has exploded.



5 The Stars in Space

Our star-system or Galaxy contains at least 100,000 million suns. Some of these form clusters, such as the famous 'Globular Cluster' in the constellation of Hercules, which is just visible to the naked eye as a hazy patch, and is well seen in a small telescope. If our Sun were a member of such a cluster, there would be many brilliant stars in the sky, and there would be no real darkness at night.

The Pleiades cluster, not far from Orion, is quite different. It contains over 200 stars, of which several are visible without a telescope; most people can see at least seven on a clear night, and it is always interesting to note how many you can count. Another cluster, the Hyades, lies round the bright reddish star Aldebaran. Then there are the nebulae, which were mentioned earlier in this book; they

are made up of gas and dust, shining because of the stars contained inside them. One lovely nebula, the Trifid, is shown on page 25. It must be added, however, that this photograph was taken with the world's largest telescope – so if you look at it, do not expect to see the beautiful colours. All you will see will be a misty patch.

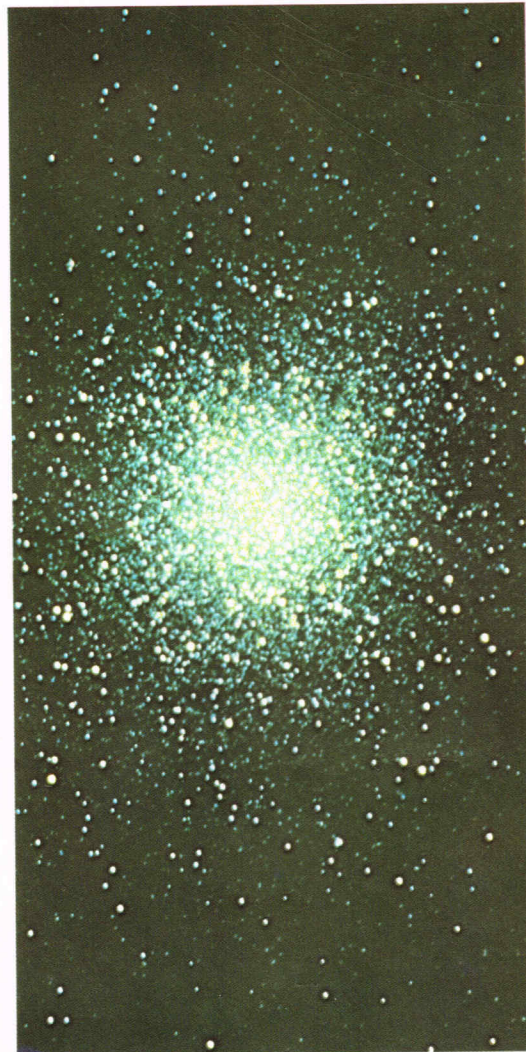
The Trifid Nebula is a stellar birth-place, just as the Crab Nebula, shown on page 23, represents the death of a star. Many other gas-and-dust nebulae are known, though unfortunately most of them are rather faint. Different again are the strange objects known as planetary nebulae, which are nothing more nor less than stars which have produced huge 'shells' of gas, so that they look rather like dim, shining bicycle-tyres in the distance.

The Galaxy itself is very large indeed. A ray of light, moving at 186,000 miles per second, would take 100,000 years to cross it from one side to the other; we say, therefore, that the diameter of the Galaxy is 100,000 'light-years'. (One light-year is equal to almost 6 million million miles.)

The shape of the Galaxy is shown in the first two diagrams on page 26. From the 'side', the shape would be rather similar to that of two fried eggs clapped together back to back, with a central bulge marked by the lovely star-clouds in the constellation of Sagittarius (the Archer). The Sun, with the Earth and the other planets of the Solar System, lies well out towards the edge. Recent measurements show that we are over 30,000 light-years from the centre of the Galaxy.

This flattened arrangement produces the magnificent band across the sky which we call the Milky Way. When we look along the main thickness of the Galaxy, we see many stars in almost the same direction; in other words, the stars seem almost one behind the other. Anyone who lives in the country, away from artificial lights, will be very familiar with the Milky Way, though city-dwellers will not often see it.

If we could have a bird's-eye view of the Galaxy, we would see it in the form of

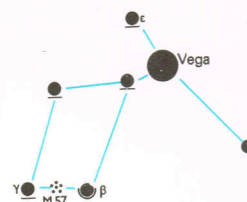
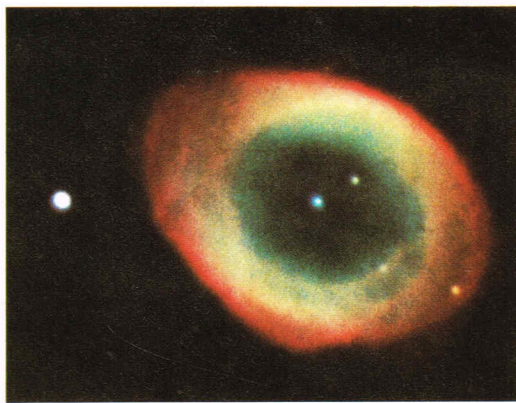


right: The Globular Cluster in Hercules.

a spiral, like a Catherine-wheel. This is shown in the left-hand diagram. The Sun lies close to the edge of one of the spiral arms, and is moving round the centre of the system; it takes over 200 million years to complete one journey.

Every one of the objects which have been described up to now belongs to our Galaxy, but there is one naked-eye patch which is much further away. This is the Great Spiral in the constellation of Andromeda, not far from the Square of Pegasus. As can be found from the seasonal maps on pages 14 and 15, Andromeda is best placed during evenings in autumn. The Spiral, known officially by its catalogue number of M.31, is easily visible with binoculars.

M.31 has the distinction of being the most remote object ever to be seen without optical aid. Its distance from us is over 2 million light-years – so that we are seeing it not as it is now, but as it used to be more than two million years ago. It is not a member of our Galaxy; it is an independent galaxy containing more than 150,000 million suns.



The Ring Nebula in Lyra. This is a planetary nebula—really a star surrounded by a huge shell of thin gas. The position of the Ring Nebula (M.57) is shown in the diagram.



left: Another view of the Pleiades.

below: The Trifid Nebula in Sagittarius.



The Spiral can be found without difficulty, and is always worth looking at, but it must be said that it is not really striking. Photographs taken with very large telescopes are needed to show it properly, and when observed with smaller instruments it seems to be a misty patch; it lies at a sharp angle to us, so that the spiral effect is not clear. With other galaxies, such as the so-called Whirlpool (page 29), photographs show the structure excellently.

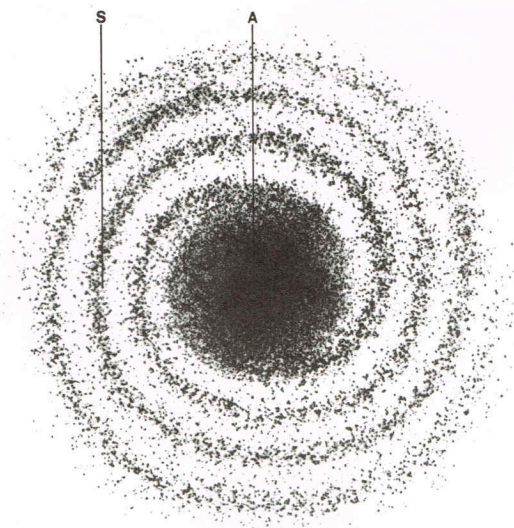
Many millions of galaxies have been found. Not all of them are spiral: some are elliptical, while others are irregular in shape. Each contains thousands of millions of stars, together with clusters and gas-nebulæ. Our own Galaxy is not in any way remarkable, though fairly large by the standards of the universe.

The Andromeda Spiral, at over 2 million light-years, is one of the nearest of these outer systems. Most of the rest are much further away, and our modern telescopes can reach out to many times this distance. Obviously, the more distant

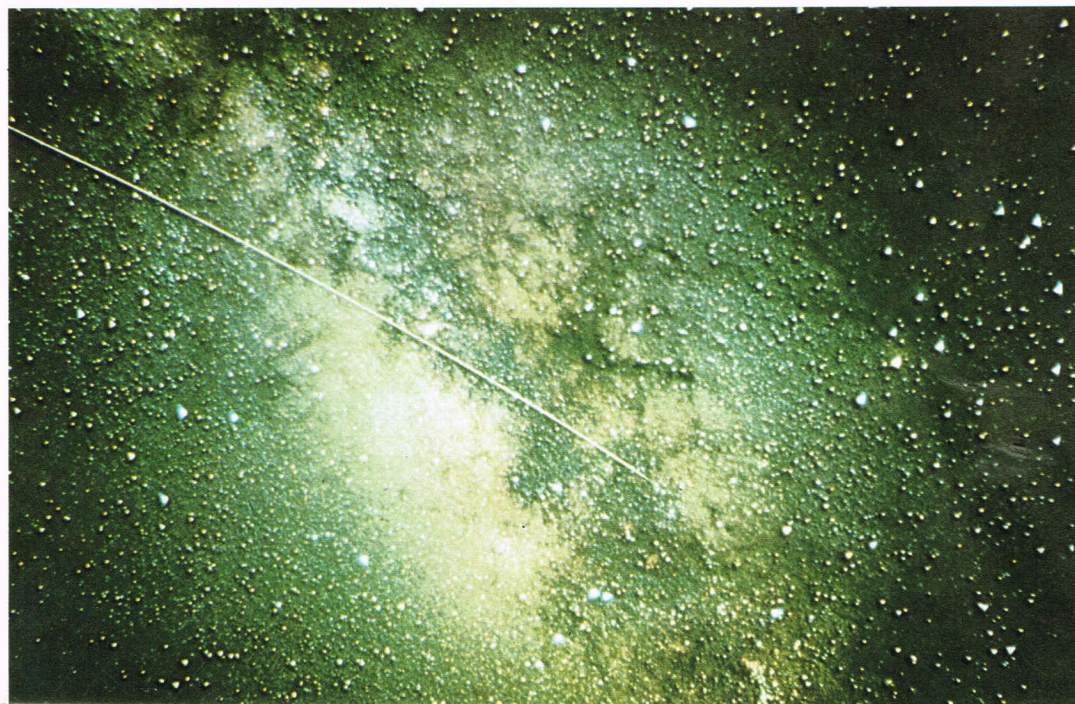
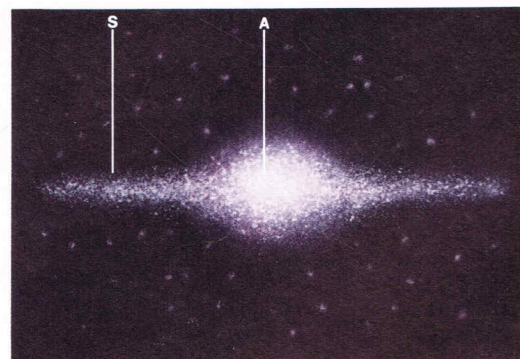
galaxies cannot be seen in such detail, and appear as blurred patches.

It is now almost fifty years since astronomers became certain that galaxies such as the Andromeda Spiral were separate systems, well outside the Milky Way. Inside the Andromeda Spiral and other galaxies of the same kind there are certain special variable stars known as Cepheids, which brighten and fade over periods of a few days. The way in which a Cepheid behaves tells us how luminous it really is – and once we know this, we can work out its distance. As soon as Cepheids had been found in the galaxies, astronomers could measure the distances of the galaxies themselves.

As well as sending us light, some of the galaxies send out longer wavelength radiations which are known as radio waves (rather a misleading name, since there is no suggestion that they are artificial). These radiations are collected and studied by means of radio telescopes, such as the Jodrell Bank instrument shown in the photograph on page 11. One famous radio source lies in the constellation of Centaurus (the Centaur), too far south to be seen from Britain. Astronomers used to think that the energy was being



Two diagrams of our Galaxy: A is the centre, while S is the position of the Solar System. First is a plan view, and then the Galaxy, imagined 'edge-on'.



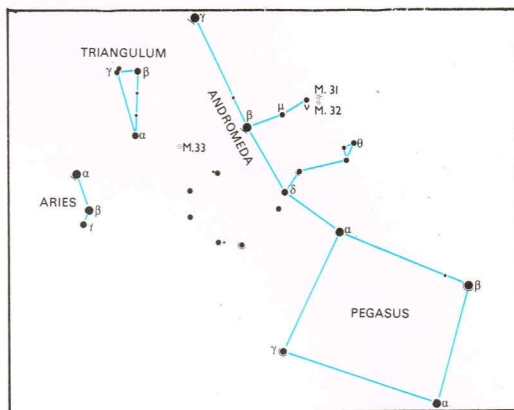
The star-clouds in Sagittarius; this is the direction of the centre of the Galaxy. The streak across the photograph was caused by an artificial Earth satellite.

produced as a result of a head-on collision between the two galaxies, but this idea has now been given up, and we have to admit that we do not know why the radio waves occur.

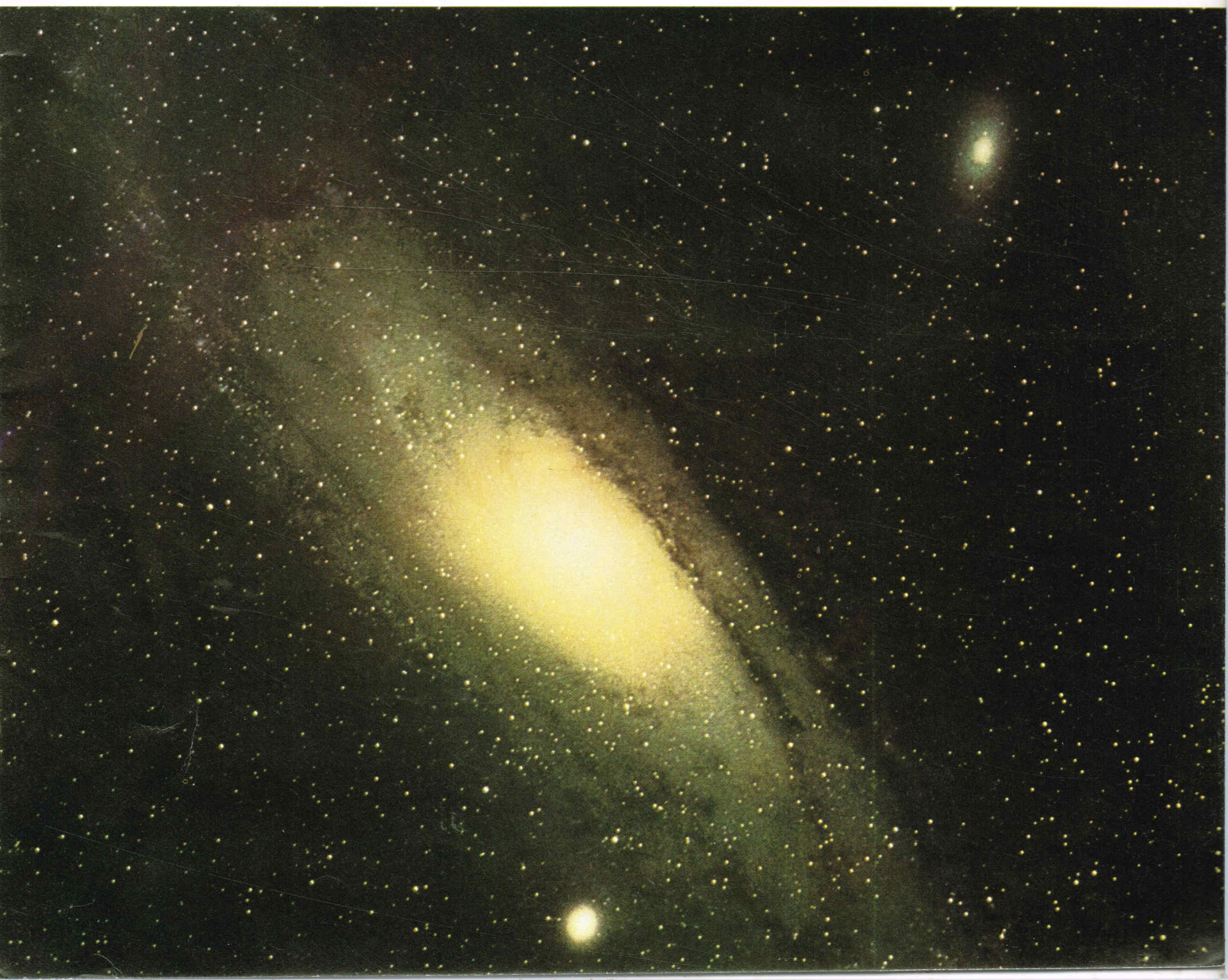
Further away still are the remarkable objects known as quasars (pronounced kway-sahs). They are much smaller than galaxies of normal type, and seem to be almost incredibly luminous. Their distances range out to at least 7,000 million light-years, so that we are seeing them as they used to be before the Earth came into existence. Quasars are very much of a mystery, and as yet we have little idea of their real nature.

The universe is a large place – and to make it even more extraordinary, it seems to be expanding. Apart from a few of the very nearest systems, such as the Andromeda Spiral, all the galaxies are racing away from us. If an object is moving away, it seems slightly redder than it would otherwise do; if the object is approaching, it looks slightly too blue. This is known

as the Doppler effect, after the 19th-century Austrian scientist. The change in colour is very slight, and cannot be noticed in everyday life; for instance, you will not see any difference in the colour of a car's headlight as it passes. However, astronomers use special instruments called spectroscopes, which split up the starlight and show the Doppler effect very clearly. When the galaxies and the quasars are studied in this way, their



The Great Spiral in Andromeda. The diagram shows Pegasus, Andromeda and the position of the Great Spiral (M.31).



speeds away from us can be measured.

What is the cause of this racing away? We do not know. Neither have we any idea of how the universe came into existence. By studying the stars and the galaxies, we can tell that the universe must be much more than 10,000 million years old, which is over twice the age of the Earth, but we cannot even be sure that there was a definite 'beginning'.

Some astronomers believe that all the material in the universe was created at one moment. There was a tremendous explosion which sent the material flying outward in all directions; gradually the galaxies were formed, and the stars were created inside the galaxies. It is easy to understand why this is often called the 'Big Bang' theory. If it is correct, then the universe will not exist for ever. The stars and the galaxies will die.

On the other hand, it has also been suggested that the universe has always existed, and will exist for ever – even though the Sun and the Earth will not! If this is true, then the galaxies will eventually come together again, and there

will be another 'big bang' to mark the beginning of a new chapter in the story.

It is a fascinating problem, but as yet we cannot solve it. Neither can we tell whether 'space' is infinite, or whether it is of limited extent. It is a problem which we find very hard to understand, and all we can really do at the moment is to study objects which are a very long way away from us, hoping that they will give us more information.

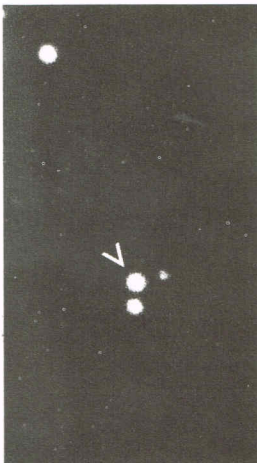
We have seen that apart from a few of the closest systems, such as the Andromeda Spiral, all the galaxies are moving away from us. It has also been found that the farther away they are, the faster they are going. We know of galaxies which are moving away at more than 150,000 miles per second, so that they are much more remote now than they were when you sat down to read this chapter. Some of the quasars are going even faster; their speeds may be 170,000 miles per second.

If this law of 'the farther, the faster' holds good, there must eventually come a distance at which a galaxy or a quasar is moving away from us at the speed of

right: Centaurus A,
which sends us radio
waves as well as
visible light.



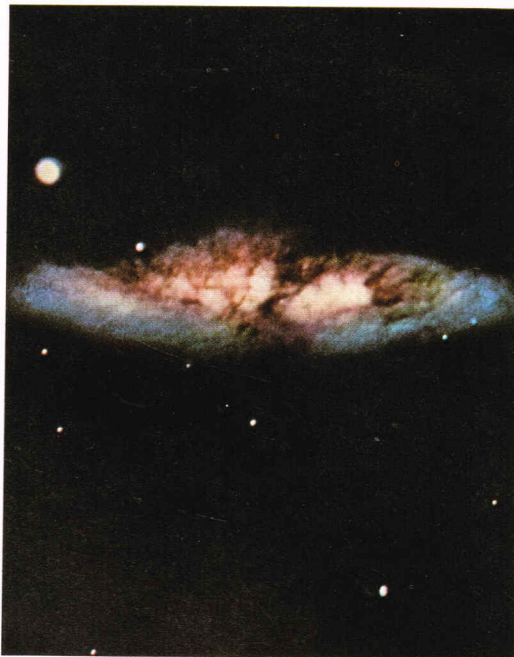
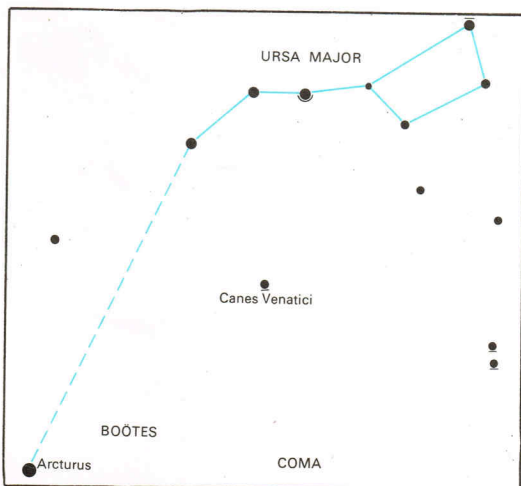
below: A quasar.



light: 186,000 miles per second. In this case its light could never reach us, and we could know nothing about it. Astronomers calculate that this distance is about 12,000 million light-years; and if so, then this is the boundary of the universe which we can study. On the other hand, conditions at these distances may not be what we think, and we cannot yet be sure what will be found. As yet we do not have either ordinary telescopes or radio telescopes which can study objects at as great a distance as 12,000 light-years. The more we look around the universe, the more we realise how little we really know.

Remember, too, that our knowledge of the universe is bound to be out of date. We depend entirely upon the light sent to us from the bodies in the sky; and even though light travels at 186,000 miles per second, it takes a long time to reach us from the galaxies. Look at the Moon, and you see it as it used to be $1\frac{1}{4}$ seconds ago; the Sun is seen as it used to be $8\frac{1}{2}$ minutes ago; Rigel in Orion as it used to be about 1000 years ago – but when we look at a quasar, we are seeing it as it used to be thousands of millions of years ago. All we can do is to collect what information we can, and try to piece it together.

Suppose that there is an astronomer living on a planet moving round a star in, say, the Andromeda Spiral? Looking up, he will see a misty patch which marks our own Galaxy, the Milky Way; he will see the spiral arms, the clusters and the nebulae, and the giant stars – but unless he has a very powerful telescope, he will not see our Sun, which is by no means important. Though we have no proof, we may be sure that there are astronomers in the Andromeda Spiral, and that at this very moment they are looking towards us. Perhaps they know much more about the universe than we have managed to learn.

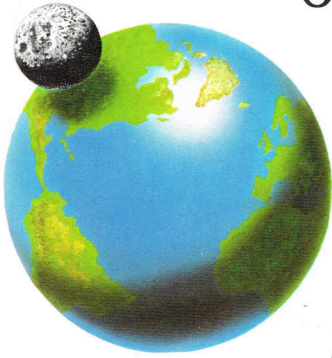


left: An irregular galaxy in Ursa Major.

below: The Whirlpool Galaxy in Canes Venatici. The diagram shows Ursa Major and the position of Canes Venatici (the Hunting Dogs).



6 The World of the Moon



The size of the Moon, compared with the Earth.



The Full Moon.

The Moon is much the closest natural body in the sky. It is only about a quarter of a million miles away from us, which is equal to ten times the distance right round the Earth's equator. Also, it always keeps company with us; it is the Earth's faithful companion.

It is not so large as our world. Its diameter is 2160 miles, and it has a gravitational pull which is much less than that of the Earth. A man who weighs 12 stones on Earth will weigh only 2 stones on the Moon, so that he will find himself feeling very 'light'. This was the experience of the first American spacemen to land on the Moon's surface. Charles Conrad, who went to the Moon in the rocket ship Apollo 12 in November 1969, said that

when walking around there he could 'hop like a bunny'.

Though the Moon looks so beautiful, it is not a friendly place. Because of its weak gravitational pull, it has lost its atmosphere, so that by now it is an airless world; nothing can breathe there, and it seems certain that there has never been any life on the Moon. Spacemen from Earth have to wear special suits, and take all their air with them.

The Moon has no light of its own. It shines by reflecting the light of the Sun, and this is why it shows what are known as 'phases'. When the Moon is between the Sun and the Earth, its dark side is turned towards us, and the Moon is 'new': it cannot be seen at all. When it is on the

opposite page:
Colonel Edwin Aldrin standing on the Moon, 21 July 1969. This photograph was taken by Neil Armstrong.



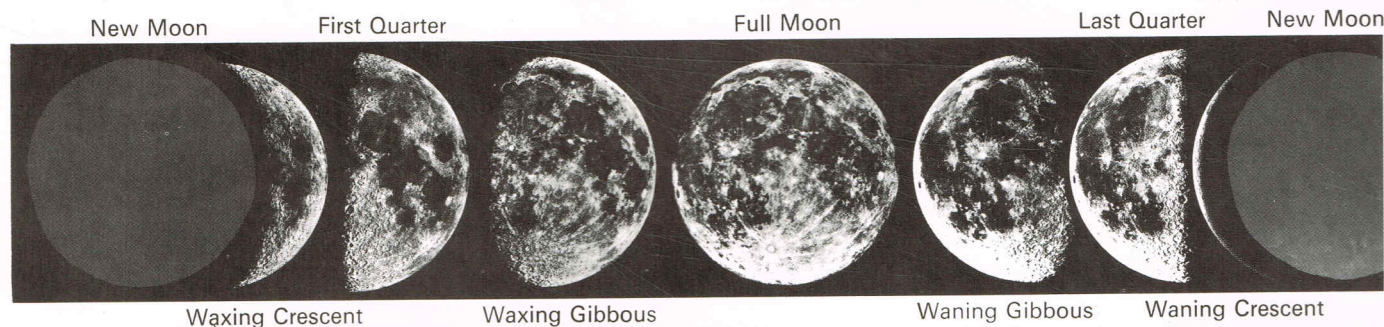
far side of the Earth with respect to the Sun (so that the three bodies are again aligned in the same direction, this time with the Earth in the middle), the whole of the sunlit side is facing us, so that the Moon is full. At other times the shape may be a crescent, a half, or a three-quarter disk. Of course, these apparent changes of shape are not real; they depend entirely upon how much we can see of the Moon's shining half. Because the Moon takes just over 27 days to go round the Earth, we have one full moon and one new moon each Earth month.

If you look at the Moon with the naked eye, you can see dark patches on it, as shown in the photograph on page 30. These patches are known as 'seas' such as the Sea of Tranquillity, the Sea of Clouds and the Ocean of Storms; but the names are not suitable, as there is no water on the Moon. The so-called lunar seas are broad, dry plains without a trace of moisture.

If you use binoculars, or a telescope, you can also see that the Moon's surface is covered with craters. These craters are of tremendous size; some of them are over 100 miles in diameter – such as Clavius, a huge enclosure which measures 144 miles from side to side. There are high mountains, too, together with hills, uplands and deep valleys.

Rather surprisingly, it is found that the time of full moon is the very worst period to start observing! This is because the sunlight is streaming straight down on the Moon's face, and there are no shadows. Also, a few of the craters are centres of bright systems of rays, which make the other features hard to identify. You can see these rays excellently in the full-moon picture on page 30. The ray-crater toward the bottom of the picture is called Tycho; it is 54 miles in diameter, and its rays spread outward for hundreds of miles in all directions. They even pass across the

below: The Moon, photographed at different phases.



above: The 144-mile crater Clavius.

below: A group of craters.



right: The Lunar Alps.



waterless seas, such as the two large plains toward the top of the picture: the so-called Sea of Showers and the Sea of Serenity.

If you look at around the time of half-moon, or when the Moon shows up as a crescent, you will have a much better view. The mountains cast long shadows, and so do the walls of the craters. When a crater is near the boundary of the sunlit part of the Moon, much of its floor will be covered with shadow, and the crater will be very striking.

Astronomers are still arguing about the way in which the Moon's craters were formed. It has been suggested that they are due to volcanic action; according to another theory, they were made by pieces of solid material which came from space and bombarded the Moon, leaving permanent scars. Certainly the lunar rocks are of volcanic type, and there must have been violent volcanic activity on the

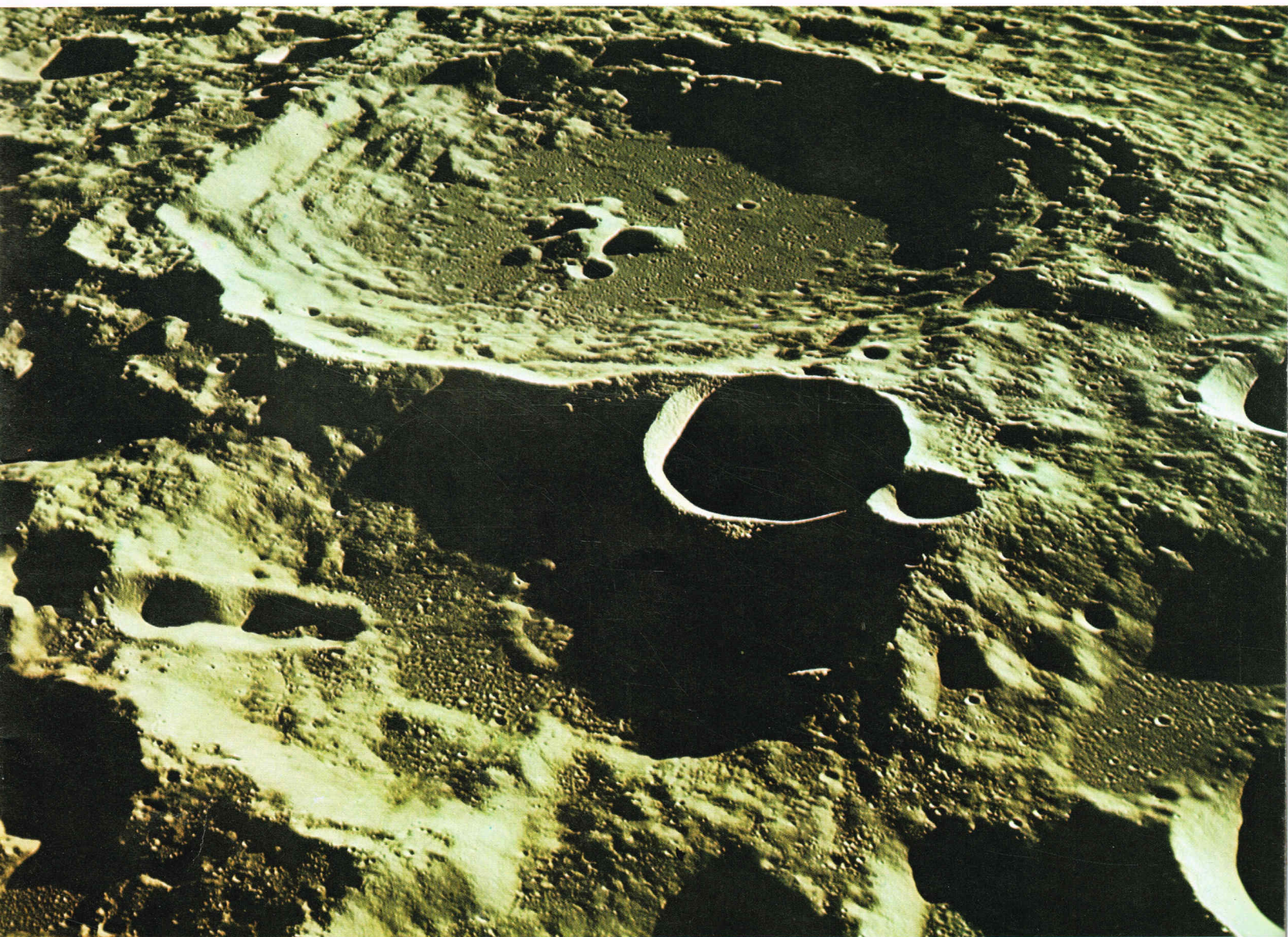
Moon many millions of years ago, but the rock specimens brought back by the Apollo spacemen are rather different from anything we find on Earth.

The Moon takes 27.3 days to spin round on its axis, so that this is the length of its 'day'. It is also the time which the



left: A piece of moon-rock brought back by the Apollo astronauts.

below: The crater Dædalus, which is on the far side of the Moon and can never be seen from Earth.

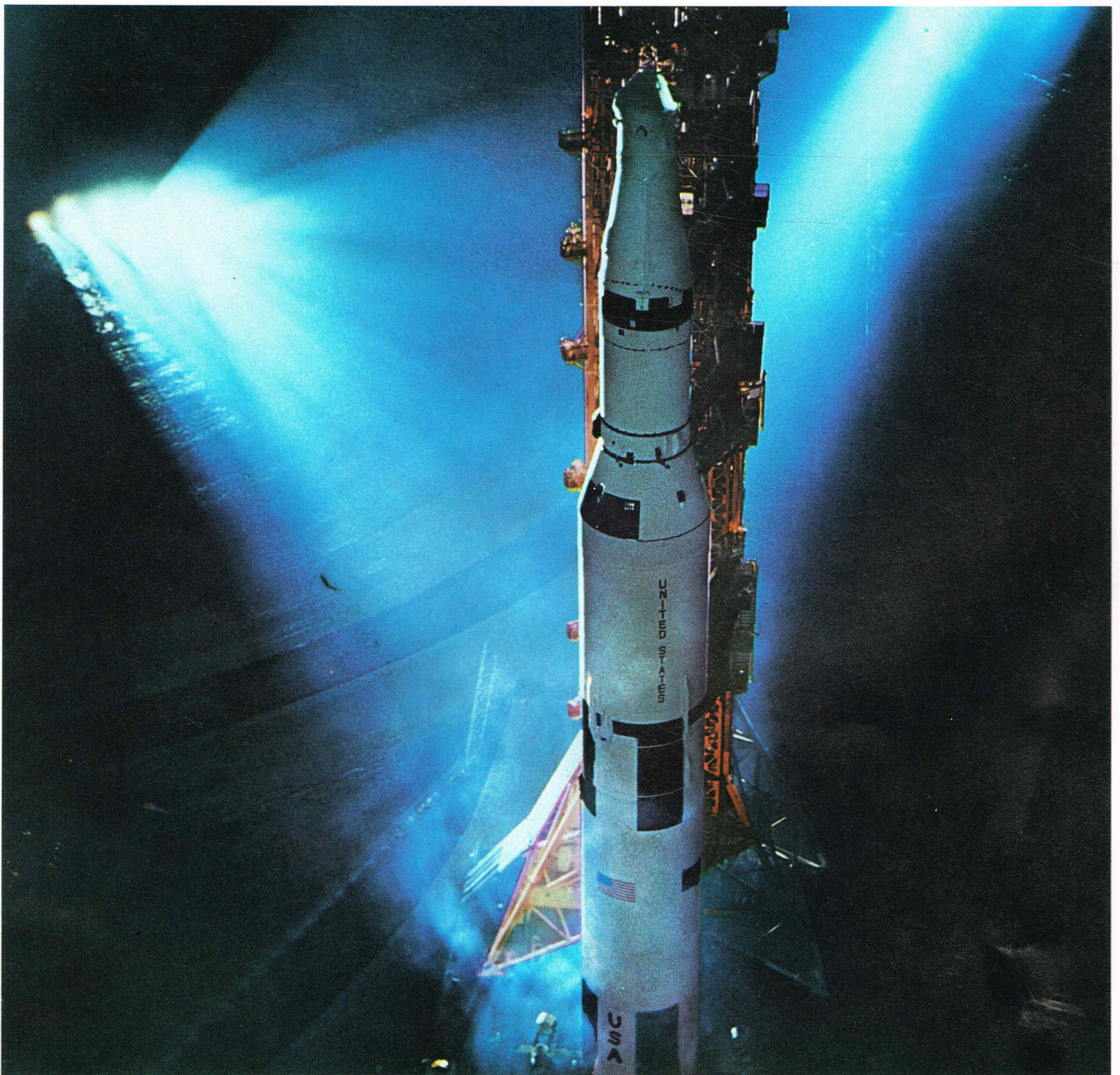


Moon takes to go once round the Earth. Therefore, the Moon keeps the same face toward us all the time. (You can show what is meant simply by walking round a chair, turning so as to keep watching the chair all the time. Anyone sitting on the chair will never see the back of your neck!) Until the time when space-rockets were built, nobody had ever seen the other side of the Moon; but by now we have detailed photographs of it. One of the photographs taken from the American Apollo 11 spaceship is shown on page 33. The large crater is called Dædalus (a name given to it in 1970, when the world's astronomers had a meeting to discuss the names of the Moon's surface features). Before the time when rockets

could be sent round the Moon, nobody really knew what the 'other side' would be like. It has been found that there are none of the large dry 'seas', but that there are large numbers of craters and valleys.

It is worth noting that although the Moon keeps the same face turned towards the Earth, it does not keep the same face turned towards the Sun. Day and night conditions are the same anywhere on the Moon; when the Sun rises, it will not set again for a period which is as long as two of our weeks. The only real difference is that an astronaut standing on the far side of the Moon will never be able to see the Earth, which will stay below his horizon all the time. This means that the nights

The launching of an Apollo spaceship.



will be darker than on the side of the Moon which is turned toward us, and which we know so well.

The Moon is an uncomfortable world. On its equator, the temperature at mid-day may rise to over 200 degrees Fahrenheit; but because the Moon has no air to blanket in the heat, the nights are bitterly cold. A thermometer would register about minus 260 degrees Fahrenheit.

As everyone knows, the first men to reach the Moon were Neil Armstrong and Edwin Aldrin in the spaceship Apollo 11. They stepped out on to the lunar Sea of Tranquillity on 21 July 1969, while their colleague Michael Collins waited for them in the other part of Apollo 11 which was circling the Moon. In the following November, Charles Conrad and Alan Bean made a landing, and stayed on the Moon for some hours; they even walked over to a crater and brought back parts of an American unmanned rocket probe, Surveyor 3, which had landed there two years earlier.

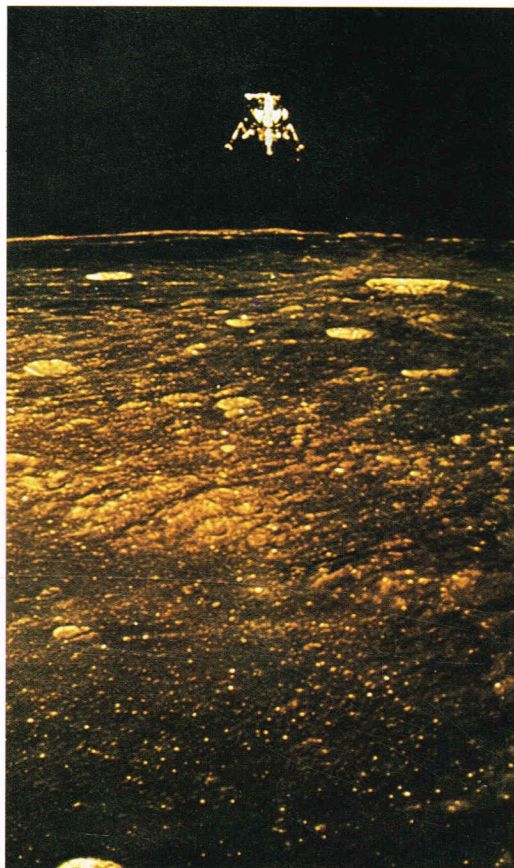
In an Apollo ship, the spacecraft itself is launched from Earth on top of a huge rocket standing over 360 feet high. The spaceship which goes to the Moon is, of course, very much smaller, and the only part of it to make a landing there is the 'lunar module', which looks very strange and spidery. The first two journeys were trouble-free, but in 1970 the third attempt, Apollo 13, almost met with disaster. During the outward trip, when the spaceship was more than 150,000 miles from Earth, there was an explosion which cut off the main power supplies. The lunar landing was abandoned, and it was only after a desperately anxious period that the three astronauts (James Lovell, Fred Haise and Jack Swigert) returned safely to Earth. The mishap to Apollo 13 was a reminder that space-travel is always a very dangerous business. However, further flights there are being planned for the beginning of 1971, and no doubt the Russians also will put a man on to the Moon before very long.

Before the year 2000, we may expect that there will be proper bases set up on the Moon. These bases will contain laboratories, astronomical observatories, and scientific equipment of all kinds. There is every reason to suppose that some of the readers of this book will themselves go to the Moon. In twenty or thirty years, lunar travel ought to be a great deal easier and more frequent than is the case at present.

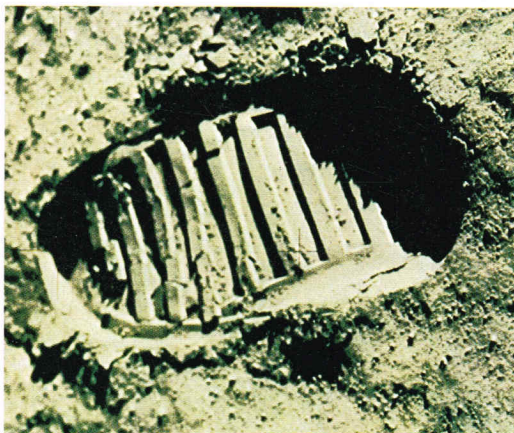
On the Moon, the stars do not twinkle;

there is no atmosphere. The Sun is blindingly brilliant, and the Earth shines down gloriously from a completely black sky. There are, as yet, few people who have been to the Moon, but many millions of people watched the first lunar landings on television, and heard the voices of the astronauts themselves as they talked to Earth.

The Moon is airless, waterless and lifeless, but because it is so close to us it is of special importance to us. Many astronomers have spent their lives in studying it – and if you turn your telescope towards it, you will be able to see the mountains, the craters, the valleys and the waterless 'seas' for yourself.



The lunar module of Apollo 12 coming down on the Moon, November 1969. Inside the module were astronauts Conrad and Bean.



Footprint on the Moon, made by Neil Armstrong.

7 The Sun's Family

The Sun is a star. It lies in the centre of the Solar System, and is much larger than any of the members of its family. It has a diameter of 865,000 miles – more than 100 times that of the Earth. The Sun is a globe of intensely hot gas, sending out energy at a tremendous rate.

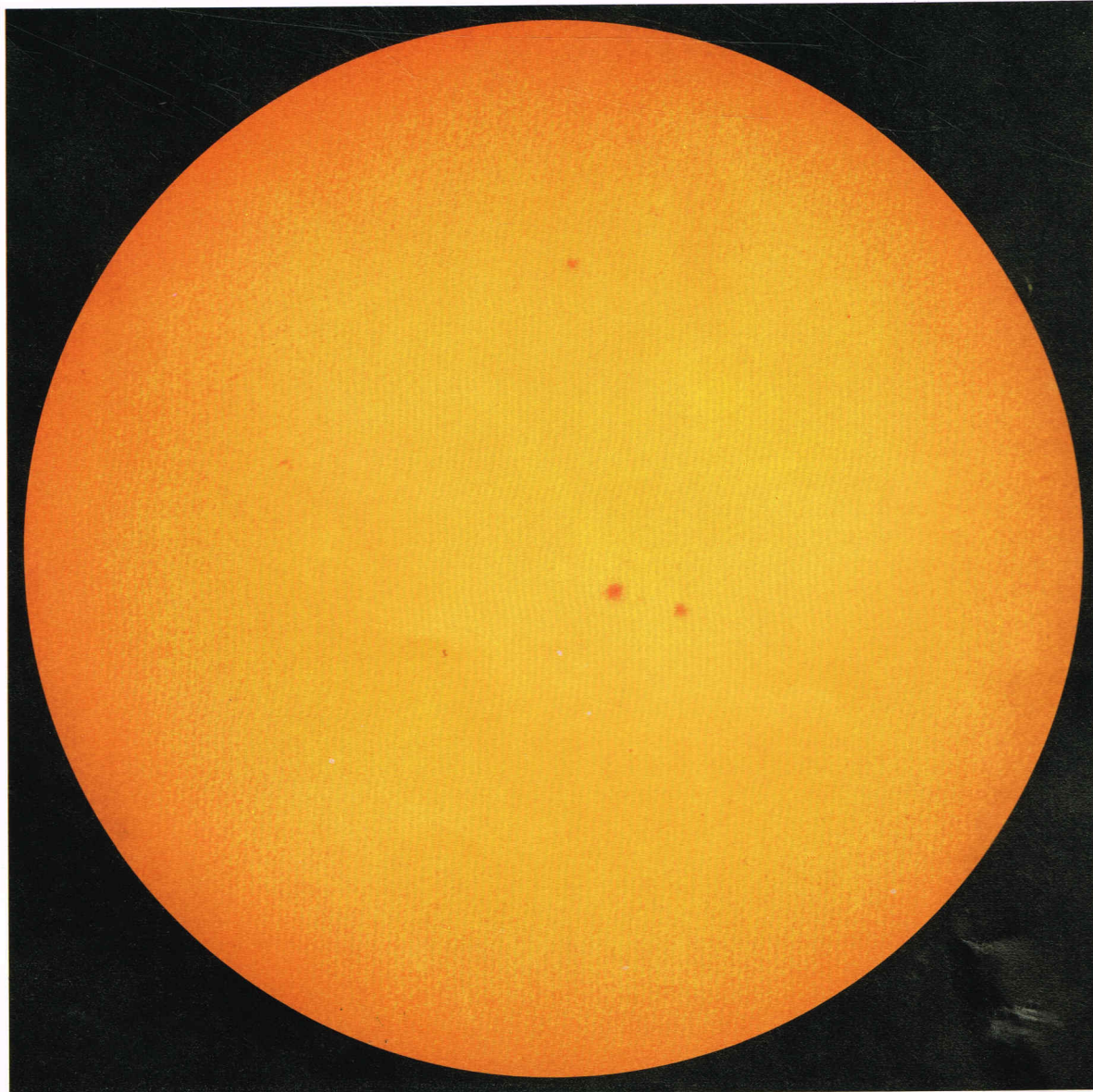
Sometimes, dark patches known as sunspots may be seen on the surface. They are interesting to watch, but *on no account* look straight at the Sun through a telescope, or even a pair of binoculars. If you do so, you will concentrate all the Sun's heat on to your eye, and you will blind yourself. Neither is it wise to stare directly at the Sun with the naked eye.

When the Moon passes between the Sun and the Earth, it 'gets in the way' of

the Sun, and hides it; this is called a solar eclipse. When the whole of the Sun is covered, we can see the Sun's outer atmosphere, known as the corona, together with masses of red gas rising from the surface. A total eclipse is a splendid sight, but it can never last for more than eight minutes. The next total solar eclipse to be visible from England will not occur until August 1999. If you want to see a total eclipse before then, you will have to travel to some other part of the world.

All the planets move round the Sun. Two of them, Mercury and Venus, are closer to the Sun than we are, so that they show phases similar to those of the Moon; occasionally they pass between the Sun and the Earth, and appear as

The Sun, showing several sunspots.

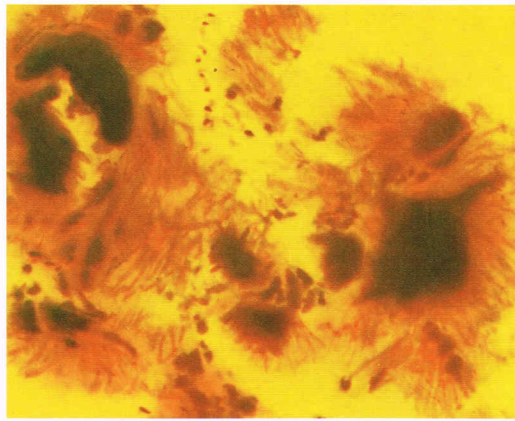


black spots in transit against the solar face. Mercury is due to transit in 1973, but Venus will not do so until 2004.

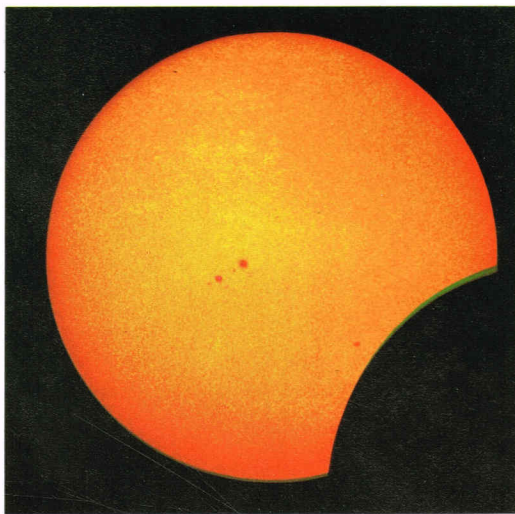
Mercury is a small world, not a great deal larger than the Moon. It is never brilliant, and there are many people who have never seen it. It has no atmosphere, and certainly we cannot expect to find any life there. A rocket, carrying automatic cameras, is expected to pass close to it within the next few years, and will send back pictures from close range. It is very likely that Mercury, like the Moon, is covered with craters.

Venus, which comes next in order of distance, is a very different place. It is almost the same size as the Earth, and is covered with clouds which reflect the sunlight brilliantly. Venus is brighter than any other object in the sky apart from the Sun and the Moon; when at its best it may even cast a shadow. It appears either in the western part of the sky after sunset, or in the east before dawn.

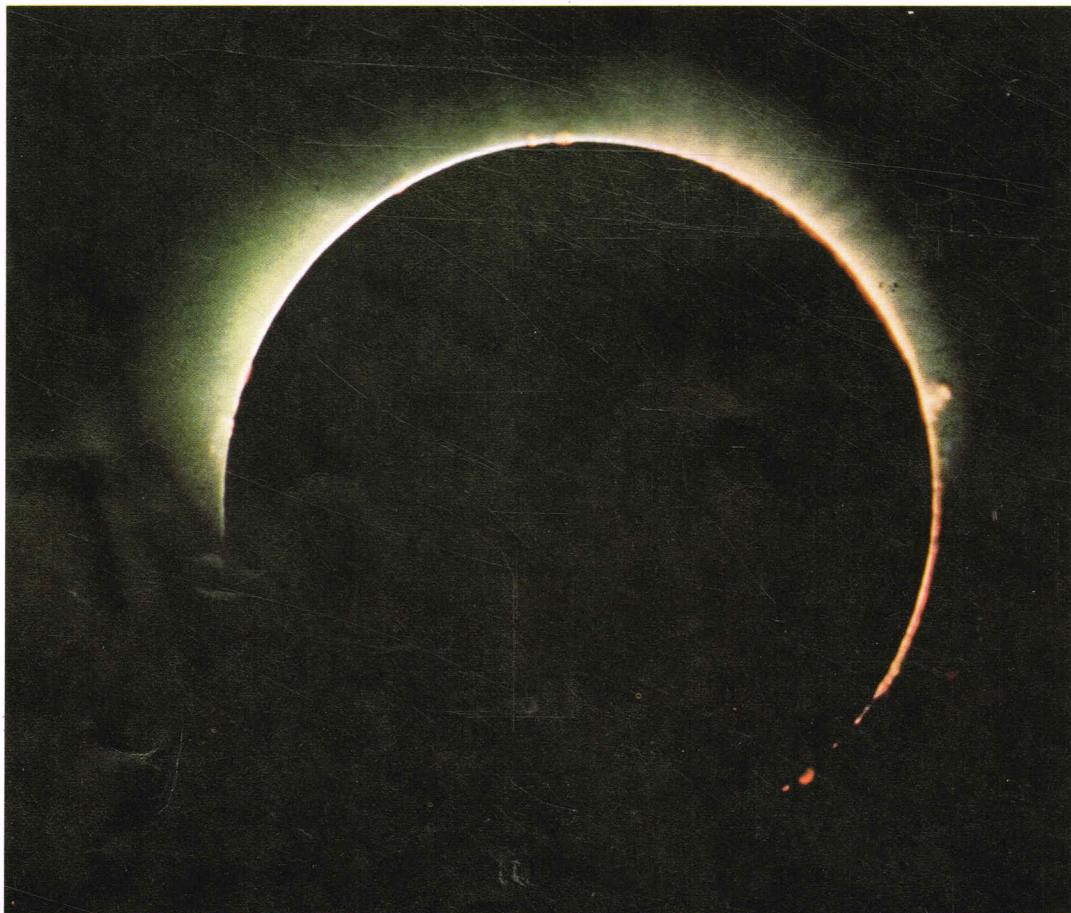
The atmosphere of Venus is very dense, and is made up mainly of the heavy gas carbon dioxide. The Russians have sent several spaceships to it, bringing them down through the planet's atmosphere by parachute, and have obtained a great deal of information. Apparently Venus is



left: Large sunspot group.



left: Partial eclipse of the Sun. The disk is partly covered up by the Moon.



left: Total eclipse, showing the masses of gas round the Sun's edge. The surface is completely hidden by the dark Moon.

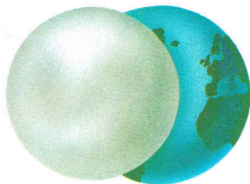
scorching hot, with a surface temperature of hundreds of degrees. There can be no life on Venus, and we cannot even be sure that men from Earth will ever be able to land there.

Beyond Venus comes the Earth; and beyond the Earth we reach Mars, which is very red, and was named after the mythological God of War – presumably because red is the colour of blood. Mars

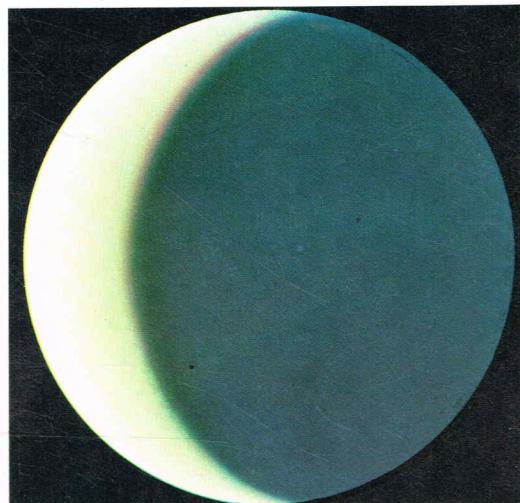
is larger than Mercury or the Moon, but smaller than the Earth. Sometimes it can become very brilliant – as it will be in August 1971. When at its brightest, it outshines every other planet apart from Venus.

Small telescopes will not show much detail on Mars, but it should be possible to make out the white caps covering the poles. It used to be thought that these

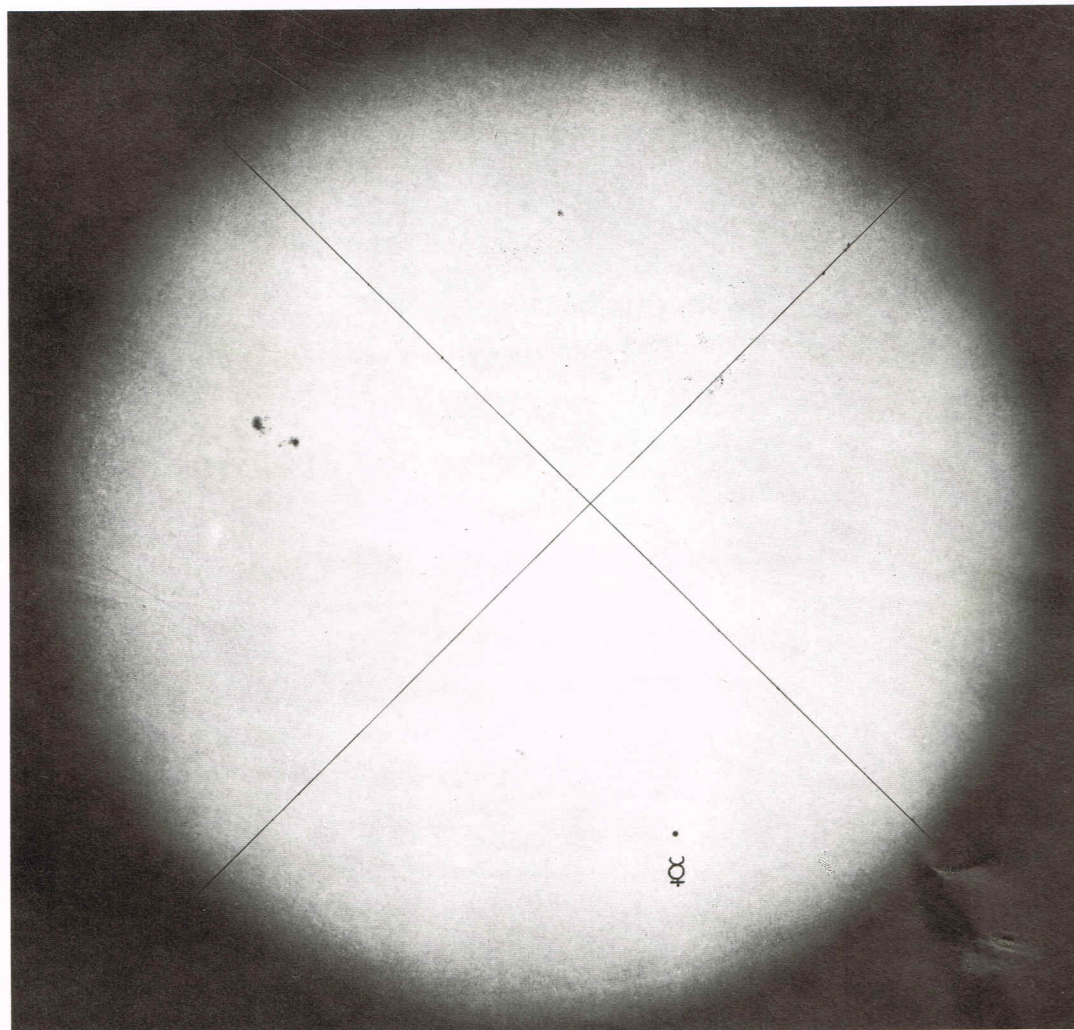
Venus and the Earth compared; they are almost equal in size.



right: Photograph of the planet Venus, and *far right* a drawing of Venus showing Ashen Light.



right: The planet Mercury, appearing as a black spot as it passes in front of the Sun. Mercury is indicated by its astronomical symbol.



Mercury and the Earth compared.



polar caps were made of ice or snow, but most astronomers now believe them to be solid carbon dioxide. The nature of the dark patches on the disk is uncertain, but it is not likely that they are due to plants. More probably, Mars is lifeless.

Several spacecraft have passed by Mars, sending back photographs from close range; the latest were Mariners 6 and 7, of 1969. These photographs have shown

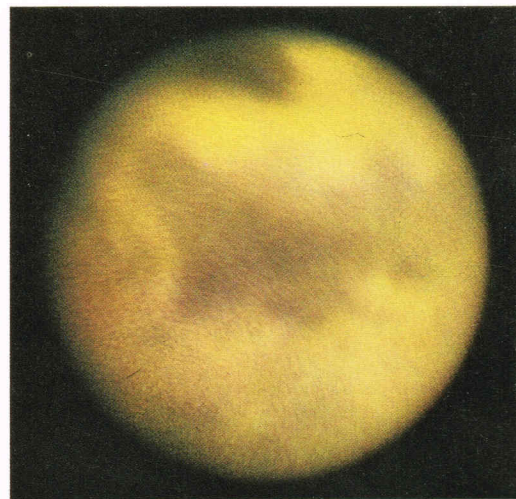
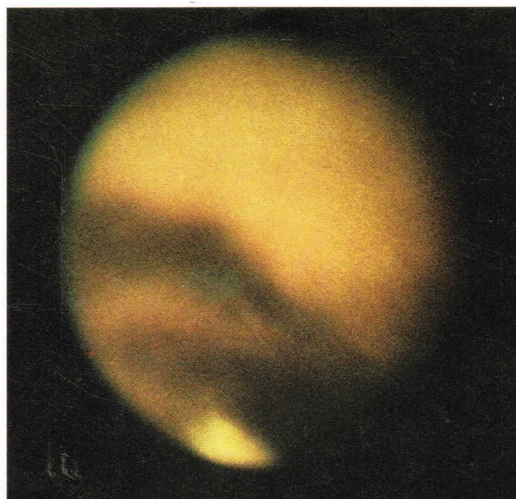
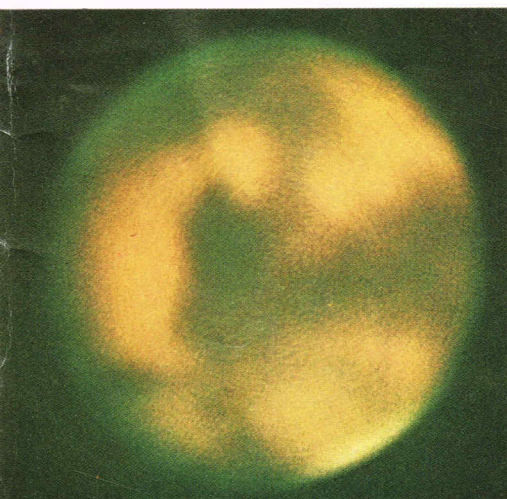
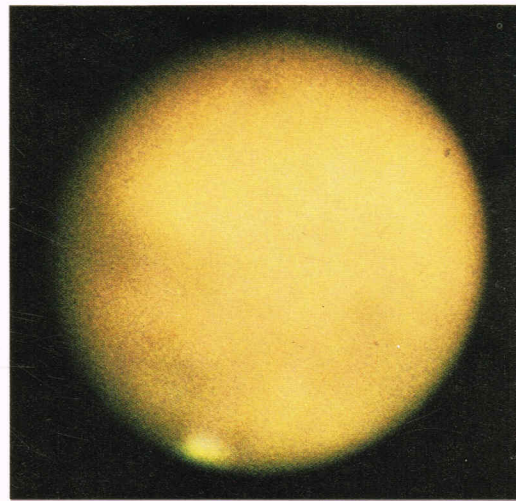
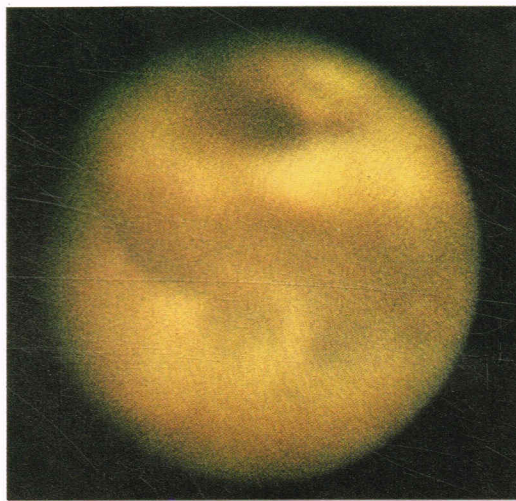
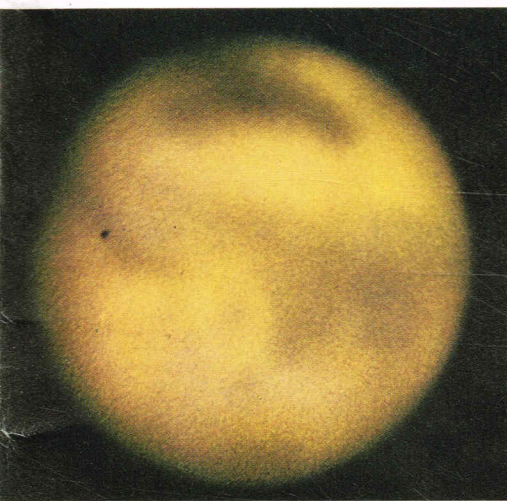
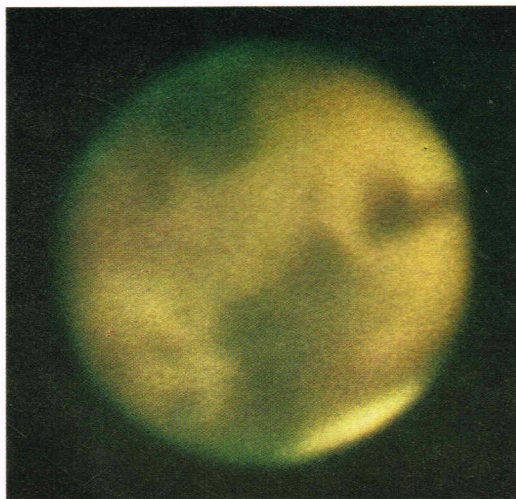
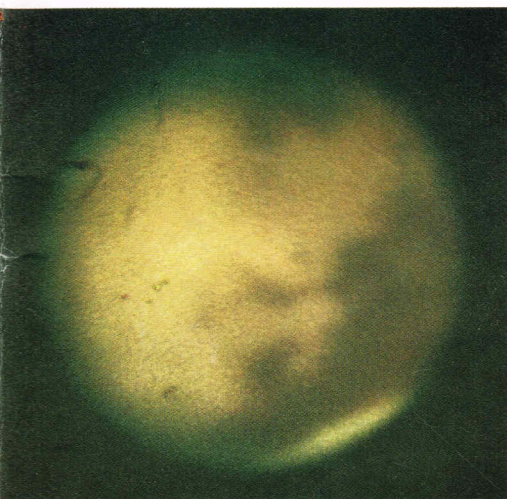
that Mars is covered with craters over wide areas of its surface, so that on the whole the planet resembles the Moon rather than the Earth. There is a very thin atmosphere, made up of carbon dioxide, so that we could not breathe it.

We have only one moon. Mars has two, named Phobos and Deimos; but with an ordinary telescope you will not be able to see them, since both are very small.



Mars and the Earth.

Photographs of Mars.



Deimos is only about 5 miles in diameter, while Phobos is shaped rather like a potato; it is about 14 miles long and 11 miles wide. Neither would give much light during the hours of darkness on Mars. Phobos takes only $7\frac{1}{2}$ hours to go once round Mars, which is much shorter than the Martian 'day' of $24\frac{1}{2}$ hours. To an observer on the planet, therefore, Phobos would appear to rise in the west and set in the east, taking $4\frac{1}{2}$ hours to pass right across the sky.

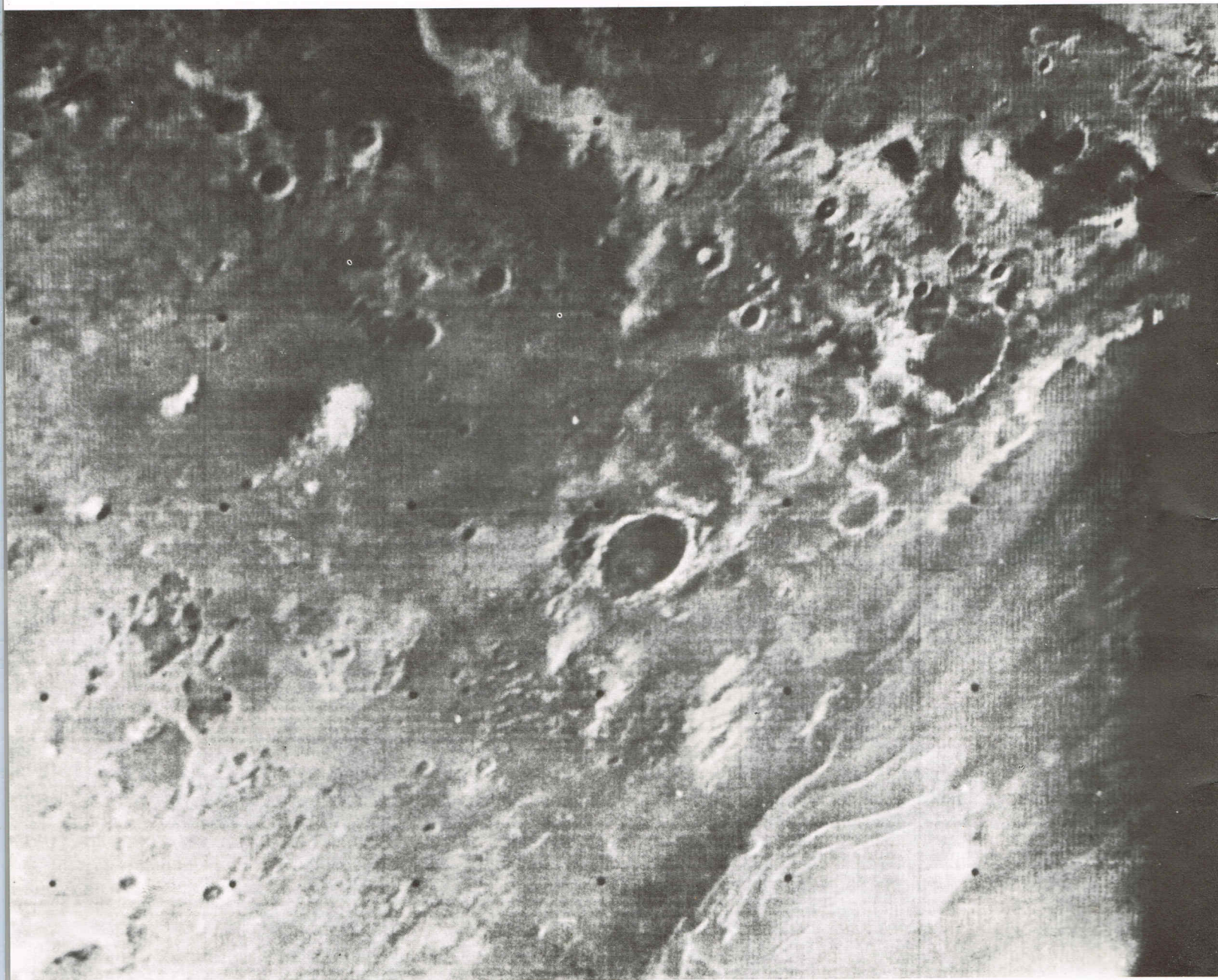
We have to admit that Mars has been a disappointment. Instead of being a friendly, life-bearing world, it has proved to be very hostile indeed. However, the other planets in the Solar System are even more unwelcoming. Jupiter, Saturn, Uranus and Neptune are made up of

gases, chiefly hydrogen and helium; they are bitterly cold, and spin round so quickly that they are obviously flattened.

Jupiter, giant of the Solar System, has a diameter over ten times that of the Earth. A small telescope will show the famous cloud belts, together with a patch known as the Great Red Spot – which has been recorded for hundreds of years, even though we do not know quite what it is. Jupiter has twelve moons or satellites, of which four can be seen with binoculars.

Saturn is smaller than Jupiter, but has a diameter of over 70,000 miles, so that it ranks as a giant. It shines as a bright, rather yellowish starlike object, and moves comparatively slowly against the constellations, because it is so far away. Telescopically, it is remarkably beautiful,

Part of the surface of Mars, photographed from the rocket ship Mariner 7 in 1969.



because it is surrounded by a system of rings. These rings are made up of large numbers of tiny particles, moving round Saturn in the manner of dwarf moons. It has been suggested that they were produced by the break-up of an old satellite, which wandered too close to Saturn and was destroyed by the powerful gravitational pull of the planet. However, Saturn still has 10 satellites left, and one of them, Titan, is visible with a small telescope.

Uranus and Neptune, too, are large worlds made up of gas, but they are well beyond Saturn, and so appear much fainter; Uranus can just be seen with the naked eye, and binoculars will show Neptune, but neither is conspicuous. Further away still comes Pluto, a strange little world which was discovered as recently as 1930. Pluto seems to be smaller than the Earth, and is, of course, too faint to be seen except with a powerful telescope. It is so far from the Sun that it takes 248 Earth-years to complete one journey; it is very cold, and must be a dismal, lonely world.

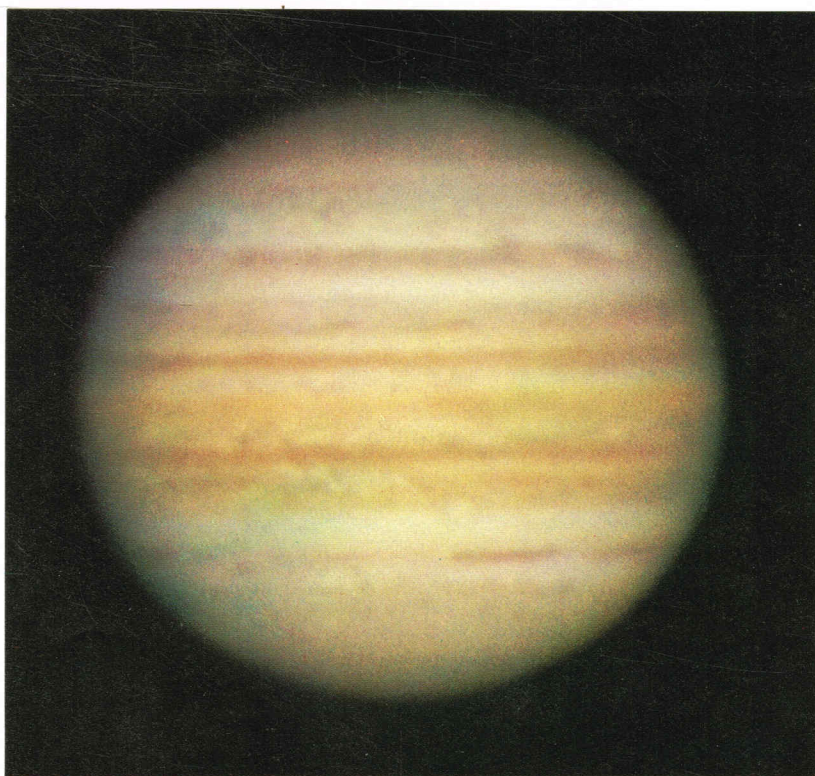
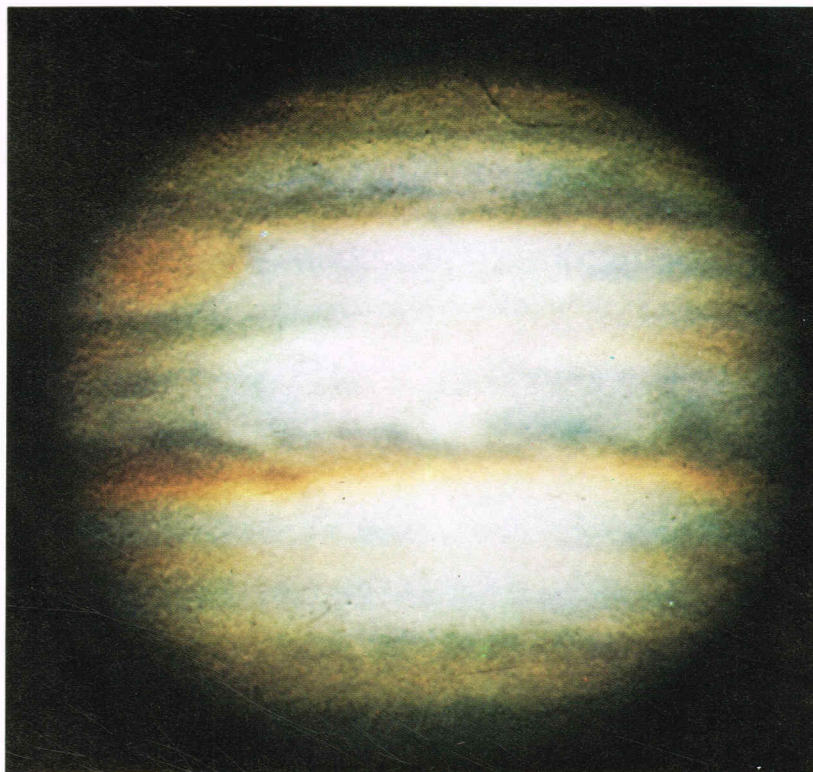
The Solar System contains many smaller bodies. There are the asteroids, or minor planets, whose orbits lie between those of Mars and Jupiter (see the diagram on page 8); Ceres, the largest of them, is only 430 miles in diameter. Some of them have strange paths which swing them away from the main swarm, and may make them come close to the Earth. Then there are the comets, which are made up of small particles together with thin gas, and which may have long tails. They move round the Sun in very 'long and narrow' paths; some of them take only a few years to make a full journey, while others take many centuries. The most famous of them is Halley's, which is bright for a few weeks every 76 years, and is due back in 1986. The brightest comet of recent years was discovered by a South African amateur astronomer named Bennett; it was striking for some days in the spring of 1970. Bennett's Comet has now moved back into the depths of space, and will not return for thousands of years.

A comet is a distant object, and does not move noticeably over a short period. If you see an object moving quickly against the stars, it cannot be a comet. It might be an artificial satellite; but if it is travelling quickly, it is likely to be a meteor.

A meteor is a tiny particle, usually smaller than a pin's head, moving round the Sun. If it enters the Earth's upper atmosphere, it rubs against the air-particles and becomes so hot that it

destroys itself in the streak of radiation which we call a shooting-star. Because meteors tend to move in clusters, we see several meteor showers each year when the Earth plunges through a swarm. The most reliable is the August shower known as the Perseids. If you look into a dark, cloudless sky between about July 29 and August 15, you will be unlucky if you do not see a meteor every few minutes.

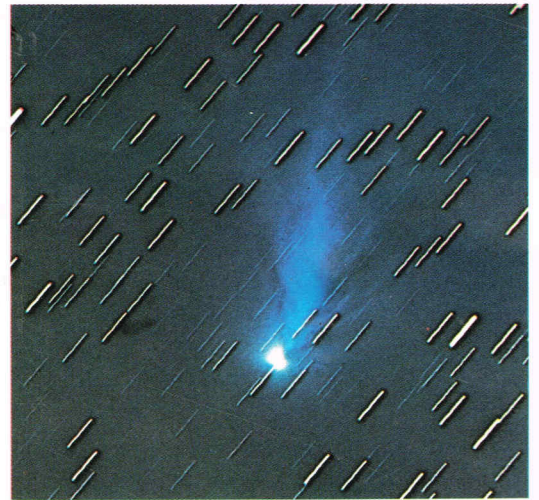
Two photographs of the planet Jupiter.





above: The Arizona Meteor Crater.

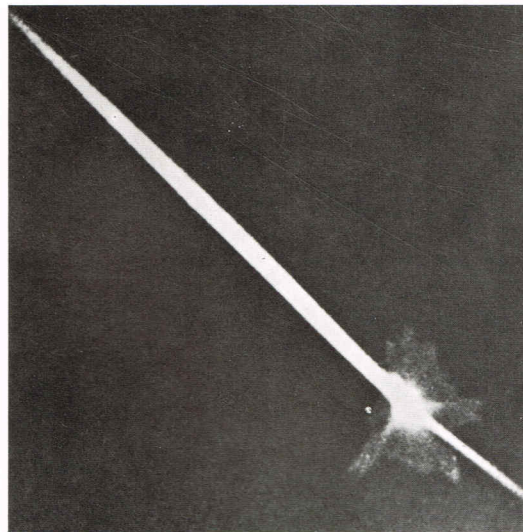
top right: Humason's Comet, 1961.



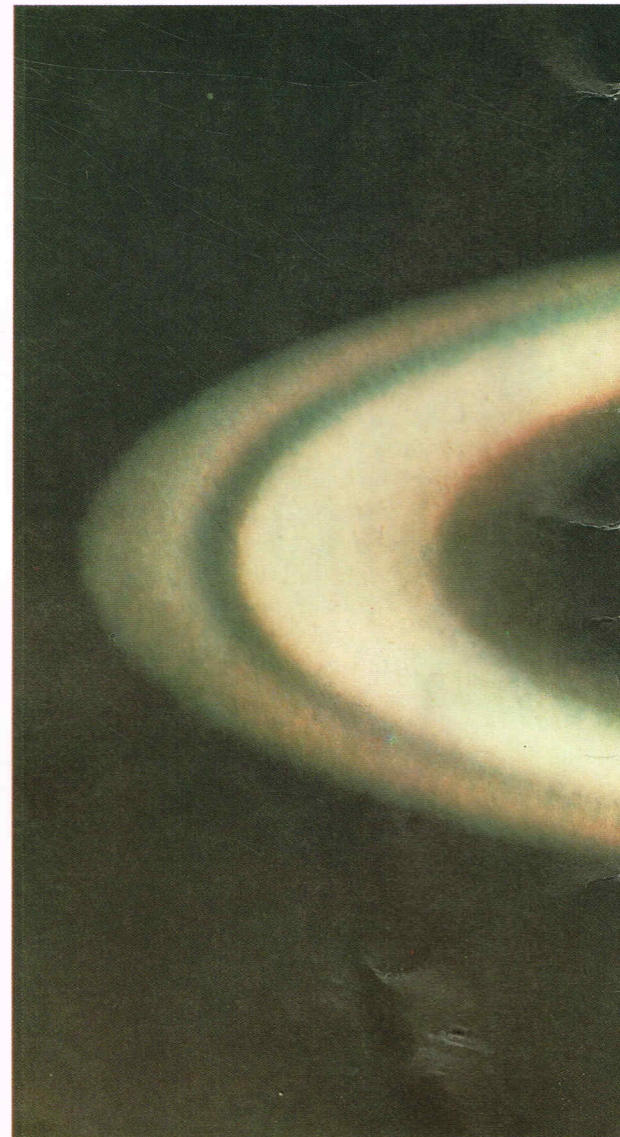
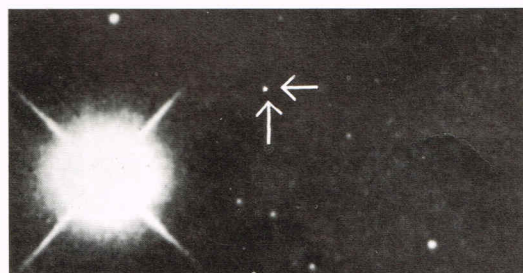
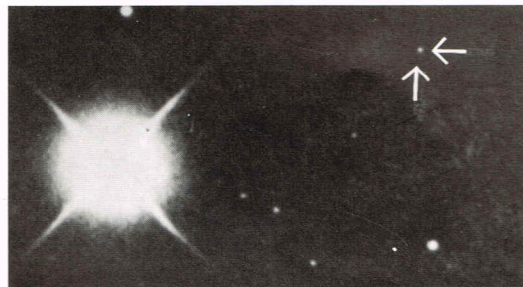
Meteors can do no damage, but now and then the Earth is hit by a much larger body which can reach ground level without being burned away, and is then called a meteorite. Most meteorites are small, but occasionally there is a really major fall. In 1908, for instance, a large meteorite

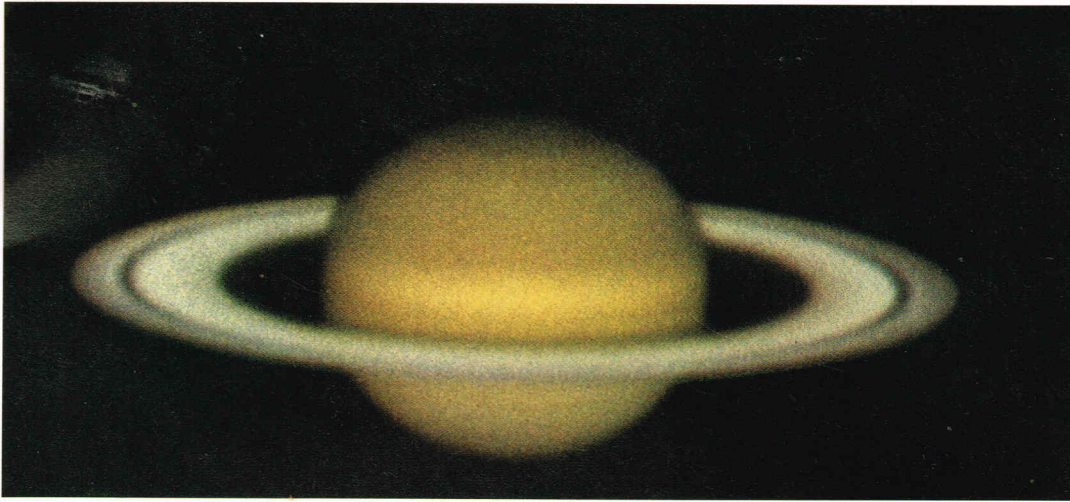
landed in Siberia, and blew pine trees flat for miles all round the spot where it hit. If it had come down on a city, many people would have been killed. Meteorites have also been known to land in England; the last occasion was on Christmas Eve 1965, when a meteorite flashed across the

right: Exploding meteor.



right: Two photographs of Pluto, seen to move relative to a very bright star.





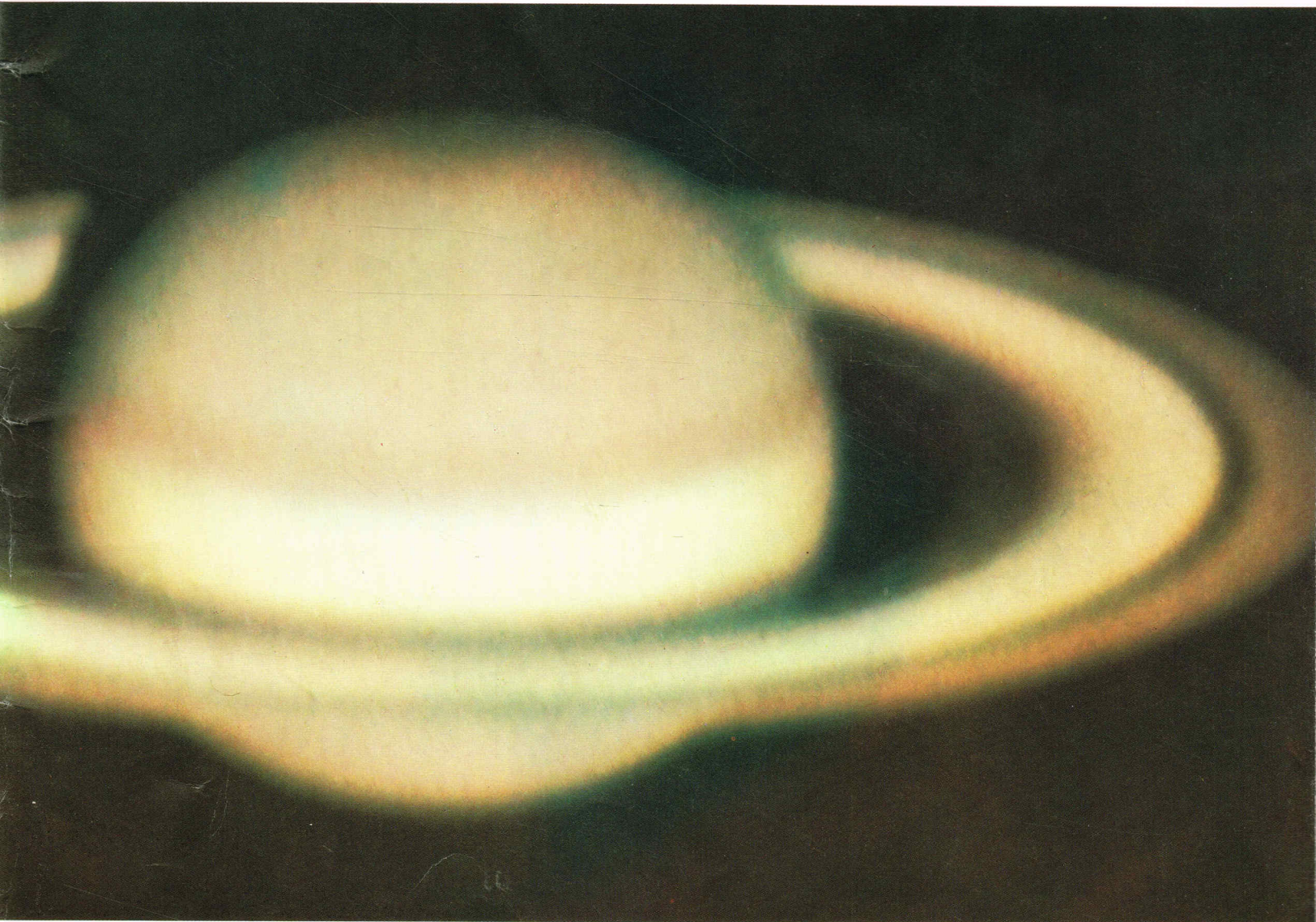
Saturn, the planet with the rings.

sky, broke up, and showered its fragments down in the region of the little Leicestershire village of Barwell. Fortunately, large meteorites are very uncommon, and there is no record that any man or woman has been killed by one.

In Arizona, in the United States, there

is a large crater almost a mile wide. Many pieces of meteorite have been found near it, and there can be no doubt that the crater was produced by a meteorite which landed in the desert thousands of years ago. If you ever go to Arizona, do not forget to go and visit Meteor Crater.

Another photograph of Saturn, with the rings more widely open.



8 Life on Other Worlds

The Earth is our home, and we are well suited to it. The climate is neither too hot nor too cold; we have lands to cultivate, water to drink, and air to breathe. Life began in the oceans thousands of millions of years ago, and has developed into the kind of life we have today.

We know that the Earth is an ordinary planet, moving round an ordinary star. All the specks of light to be seen in the photographs on this page are themselves suns, many of which may have planet-families of their own. What, then, are the chances of our being able to get in touch with 'other men'?

We must begin near home, and look first at the members of the Sun's family. Unfortunately, all these seem to be hopelessly unfriendly. Men have reached the

Moon, and have found no trace of life either past or present. This was only to be expected, because the Moon has no air – and life cannot exist without atmosphere. Of the planets, Mercury too is airless; Venus is too hot, as well as having the wrong kind of atmosphere; and all the planets beyond Mars are far too cold. Mars itself may possibly have very low-type life on it, but nowadays most astronomers prefer to think that there is no life there at all. Certainly there can be no intelligent beings.

In our search, we must therefore look farther out into the star-system or Galaxy. There are plenty of stars from which to choose; in the whole Galaxy there are at least 100,000 million suns, many of which are very like our own. The trouble is that



Star-clouds in the Milky Way. Every dot of light is a sun.

our telescopes cannot show any planets which may be moving round other stars. A planet is comparatively small, and has no light of its own, so that across great distances it is too faint to be seen.

On the other hand, it is reasonable to think that 'other Earths' do exist, and that they support life. Most astronomers believe that the planets in our own Solar System were formed out of a huge cloud of dust and gas which used to surround the Sun. If this is so, systems of the same kind must be common in the Galaxy; and any planet with similar characteristics to the Earth will be suitable for the development of advanced life.

If this is so, then we must try to decide whether we shall ever be able to communicate with other civilisations. The difficulties are very great. We can send a rocket to the Moon in a few days, and to Mars or Venus in a few months; but to send a spaceship to the nearest star would take many thousands of years. Even light, moving at 186,000 miles per second, needs over 4 years to complete

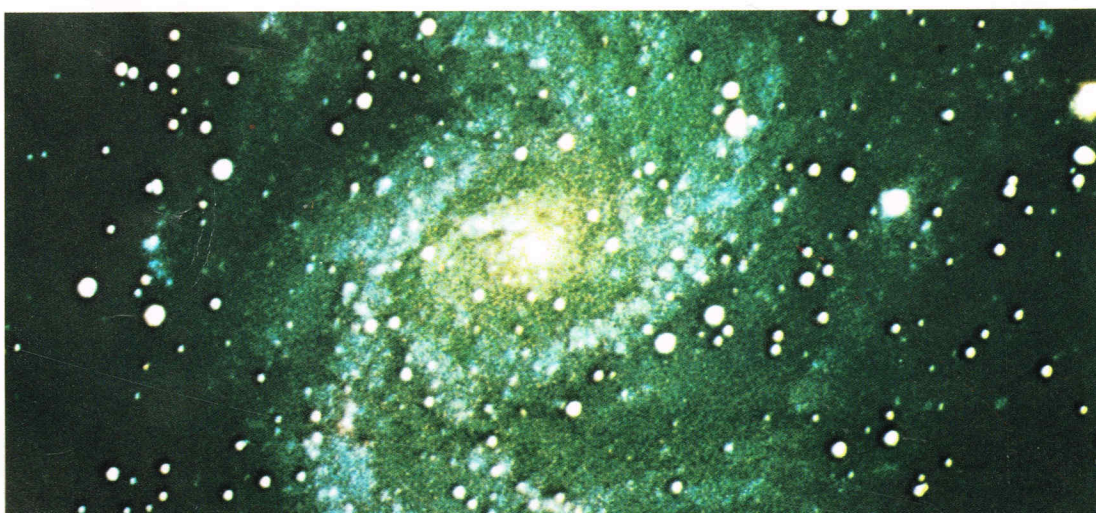
the journey. The only hope of contact seems to be by sending radio messages, but it is not possible yet, and we cannot prove that 'other men' exist.

Yet we can hardly believe that we are alone. Beyond our Galaxy there are millions upon millions of other galaxies, each containing thousands of millions of suns, and it is likely that civilisations are to be found in many places. At this very moment there must surely be a far-away astronomer who is looking upward and seeing our Milky Way system as a faint blur of light in *his* sky. He can know nothing about the Earth, or even the Sun; but he may be saying to himself, 'Yes, there must be life in that galaxy. I wonder what the creatures there are like?'

I hope you have enjoyed reading this book. If you have been interested, then I suggest that you go outside on the next clear night, take the star-maps with you, and start doing some observation. I wish you all success.



left: The 'North America' nebula in Cygnus.



left: A spiral galaxy.

Constellations, Stars and Planets

The most important constellations are given in capitals. Constellations too far south to be easily seen in Britain are not given.

Clusters, Nebulae and Galaxies

Astronomers know these by their catalogue numbers. The Messier (M.) Catalogue of 1781 lists over 100 objects and is still used, despite the more recent official New General Catalogue (NGC), which includes many more.

Stars visible in Britain in order of brightness:

- 1 Sirius
- 2 Arcturus
- 3 Vega
- 4 Capella
- 5 Rigel
- 6 Procyon
- 7 Betelgeux
- 8 Altair
- 9 Aldebaran
- 10 Antares
- 11 Spica
- 12 Fomalhaut
- 13 Pollux
- 14 Deneb
- 15 Regulus
- 16 Castor

Constellation	English name	Brightest star(s)	Best evening siting
ANDROMEDA	Andromeda	Alpheratz	Autumn
Aquarius	The Water-bearer		Autumn
AQUILA	The Eagle	Altair	Summer
Aries	The Ram	Hamel	Autumn
AURIGA	The Charioteer	Capella	Winter
BOÖTES	The Herdsman	Arcturus	Spring
Camelopardalis	The Giraffe		All the year
Cancer	The Crab		Spring
Canes Venatici	The Hunting Dogs	Cor Caroli	Spring
CANIS MAJOR	The Great Dog	Sirius	Winter
Canis Minor	The Little Dog	Procyon	Winter
Capricornus	The Sea-goat		Autumn
CASSIOPEIA	Cassiopeia		All the year
Cepheus	Cepheus		All the year
Cetus	The Whale		Autumn
Coma Berenices	Berenice's Hair		Spring
Corona Borealis	The Northern Crown	Alphekka	Spring
Corvus	The Crow		Summer
Crater	The Cup		Summer
CYGNUS	The Swan	Deneb	Summer
Delphinus	The Dolphin		Summer
Draco	The Dragon		Summer
Equuleus	The Little Horse		Summer
GEMINI	The Twins	Pollux, Castor	Winter
Hercules	Hercules		Summer
Hydra	The Sea-Serpent	Alphard	Summer
Lacerta	The Lizard		Spring
LEO	The Lion	Regulus	Spring
Leo Minor	The Little Lion		Spring
Lepus	The Hare		Winter
Libra	The Scales		Summer
Lynx	The Lynx		All the year
LYRA	The Lyre	Vega	Summer
Monoceros	The Unicorn		Winter
Ophiuchus	The Serpent-bearer	Ras Alhague	Summer
ORION	The Hunter	Rigel, Betelgeux	Winter
PEGASUS	The Flying Horse		Autumn
PERSEUS	Perseus	Mirphak	Winter
Pisces	The Fishes		Autumn
Piscis Austrinus	The Southern Fish	Fomalhaut	Autumn
Sagitta	The Arrow		Summer
SAGITTARIUS	The Archer		Summer
SCORPIUS	The Scorpion	Antares	Summer
Scutum	The Shield		Summer
Serpens	The Serpent		Summer
Sextans	The Sextant		Spring
TAURUS	The Bull	Aldebaran	Winter
Triangulum	The Triangle		Autumn
URSA MAJOR	The Great Bear		All the year
Ursa Minor	The Little Bear	Polaris	All the year
VIRGO	The Virgin	Spica	Spring
Vulpecula	The Fox		Summer

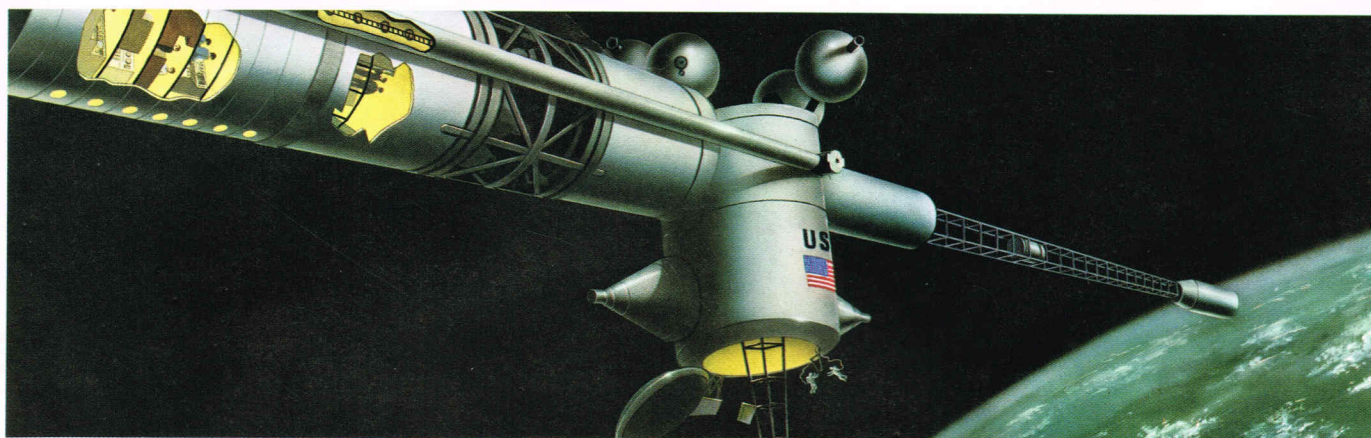
Satellites of the Planets:

- Earth : 1
Mars : 2
Jupiter : 12
Saturn : 10
Uranus : 5
Neptune : 2

Planet	Mean Distance from Sun, miles	Period of revolution	Axial rotation	Diameter miles
Mercury	36,000,000	88 days	58½ days	2900
Venus	67,000,000	224.7 days	243 days ?	7700
Earth	92,957,000	365.25 days	24 hours	7926
Mars	141,500,000	687 days	24½ hours	4200
Jupiter	483,000,000	11.9 years	9 hours 50 minutes	88,700
Saturn	886,000,000	29.5 years	10 hours 14 minutes	75,100
Uranus	1,783,000,000	84 years	10 hours 48 minutes	29,300
Neptune	2,793,000,000	164.8 years	About 14 hours	31,200
Pluto	3,666,000,000	247.7 years	6 days 9 hours	4000 ?

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SEEING STARS

Seeing Stars is a series of 8 short television programmes on BBC-1, in which Patrick Moore explains astronomy to young people.

This book will provide an accompaniment to the series. There is an expanded version of Patrick Moore's talks, with star-maps and a lot of colour pictures—not only of the Moon and those stars that can be seen on a clear night, but also of the Earth from space and stars, nébulae and planets that can only be seen through binoculars or telescopes.

Patrick Moore appears often on television. His Sky at Night programmes can be seen every month, and he is a regular member of the studio team for Apollo moon-flights.